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EMG Activity of Selected Trunk and Hip Muscles During a Squat Lift: Effect of Varying the Lumbar Posture

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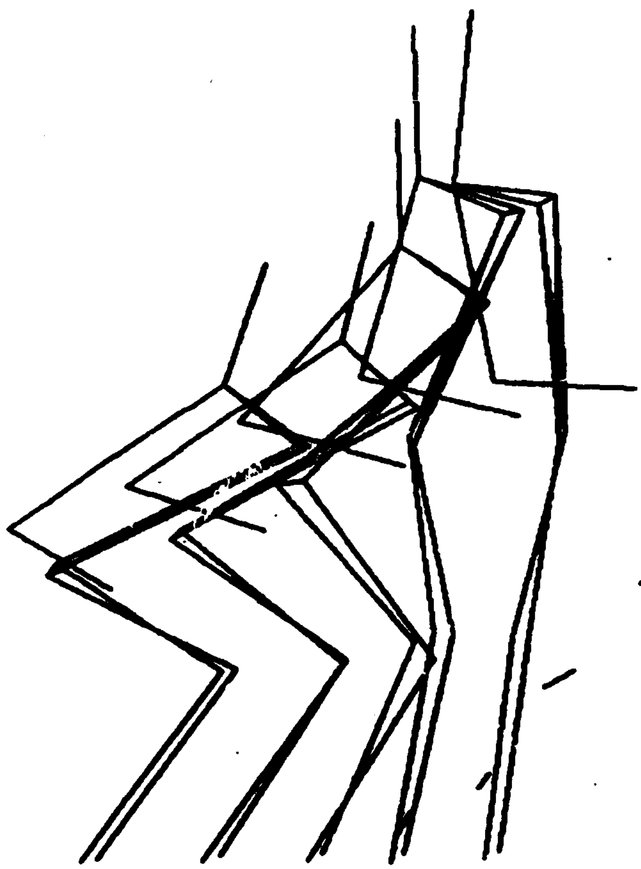
EMG Activity of Selected Trunk and Hip Muscles During a Squat Lift: Effect of Varying the Lumbar Posture



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1990

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James P. Vakos

The Graduate School

University of Kentucky

1990

ABSTRACT OF THESIS

EMG ACTIVITY OF SELECTED TRUNK AND HIP MUSCLES DURING A SQUAT LIFT: EFFECT OF VARYING THE LUMBAR POSTURE

The electromyographic (EMG) activity of selected hip and trunk muscles was recorded during a squat lift and the effects of two different lumbar spine postures were examined. Seven muscles were analyzed: rectus abdominis (RA), abdominal oblique (AO), erector spinae (ES), latissimus dorsi (LD), gluteus maximus (GM), biceps femoris (BF), and semitendinosus (ST). The muscles were chosen because of their attachment to the thoracolumbar fascia and their potential to act on the movement of the trunk pelvis and hips. Seventeen healthy male subjects participated in this study. Each subject performed three squat lifts with the lumbar spine in both a lordotic posture and a kyphotic posture. The lift was divided into four equal time phases. EMG activity of each muscle was quantified for each quarter of the lift and normalized to the peak amplitude of a maximal isometric contraction and to the peak amplitude recorded during the activity. A two-way analysis of variance for repeated measures was used to analyze the effects of posture on the amount and timing of EMG activity during the lift. Two different patterns of EMG activity were observed in this study: a trunk muscle pattern (RA, AO, ES, and LD) and a hip extensor muscle pattern (GM, BF, ST). In the trunk muscle pattern, EMG activity was at a maximum in the first quarter and decreased throughout the remainder of the lift. In the hip extensor muscle pattern the EMG activity was at its minimum level in the first quarter, increased in the second and third quarters before plateauing or decreasing in the fourth quarter. Differences ($p<.05$) were seen between subjects and between phases of the lift in all muscles. A comparison of the two lumbar postures revealed differences ($p<.05$) in ES EMG activity in quarters one, three, and four, and in the ST muscle EMG activity in quarter four. The increased EMG activity seen in the lordotic lift in the first quarter indicates the ES muscle is involved to a greater extent in the support of the lumbar spine. The greater ES EMG activity seen in the third and fourth quarters in the kyphotic lift and the greater ST EMG activity observed during the fourth quarter in the lordotic lift appears to be the muscle action required for the final reestablishment of the upright posture.

James P. Vaker
(Author's Name)

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EMG ACTIVITY OF SELECTED TRUNK AND HIP MUSCLES DURING A SQUAT LIFT: EFFECT OF VARYING THE LUMBAR POSTURE

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EMG ACTIVITY OF SELECTED TRUNK AND HIP MUSCLES DURING A SQUAT LIFT: EFFECT OF VARYING THE LUMBAR POSTURE

THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science
at the University of Kentucky

By

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1990

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION AND STATEMENT OF THE PROBLEM

Low back pain is one of the most common medical problems seen in the United States, affecting 85% of all persons at some time during their lives (Bigos, 1986; Spengler, 1986). People are most commonly afflicted in their most productive years, between the ages of 25 and 60 (Bigos, 1986) making low back pain the most expensive medical condition for people in the 30-50 age group (Spengler, 1986). Overall, it is the third leading cause of disability in the United States and for people under age 45 it is the most common. (Bigos, 1986; Sullivan, 1989). In 1976 it was estimated that in excess of $14 billion was expended on the treatment of low back pain and for compensation secondary to disability caused by low back pain (Spengler, 1986). One-fourth of all compensation for industrial injuries is from low back pain (Bigos, 1986; Delitto, 1987; Gagnon, 1985; McGill, 1985; Spengler, 1986; Sullivan, 1989). Bigos (1986) in a survey of the airline manufacturing industry found improper lifting and materials handling to be the most commonly cited causes of back injuries. Although lifting is a common activity in many occupations and has been studied extensively, the support mechanisms and forces sustained by the body are still not fully understood (Delitto, 1987; Sullivan, 1989).

Lifts are usually categorized into two main styles; squat and stoop (Andersson, 1976, 1977; Sullivan, 1989; Troup, 1977). A squat lift is performed by bending at the hips and knees, so that the body is lowered down to the object to be lifted. The stoop lift is executed by bending at the waist with the knees kept relatively straight. During a squat lift an individual's lumbar spine can assume a lordotic, (back bowed in), or a kyphotic, (back bowed out) posture. The stoop lift always has a kyphotic posture (Delitto, 1987; Hart, 1986). Lifting with the lumbar spine in a lordotic posture is believed to decrease the strain on the ligamentous system (Delitto, 1987; Hart, 1986), while lifting in a kyphotic posture is hypothesized to decrease the compressive force on the spine (Gracovetsky, 1985, 1981).

Lifting has been studied extensively by a number of researchers (Andersson, 1977, 1976; Delitto, 1987; Ekholm, 1982; Hart, 1986; Hemborg, 1983; Kipper 1984; McGill, 1987; Sihvonen, 1988; Zetterberg, 1987). Analysis of the electromyographic (EMG) signal of a muscle group during lifting can provide insight into the force developed by that muscle (Anderrson, 1977; Jonsson, 1985). Myoelectric activity of a muscle has been found to vary linearly with the tension developed, in similar activities and non-fatigue situations (Andersson, 1977; Jonsson, 1985). An increase in the level of EMG activity indicates an increase in force production by the muscle, but the precise magnitude of the force is unknown.

Most electromyographic studies of lifting have been focused on trunk muscle activity, rectus abdominis muscle, external oblique abdominal muscle, erector spinae muscles, and latissimus dorsi muscle, when lifting in different postures (Andersson, 1977, 1976; Delitto, 1987; Ekholm, 1982; Hart, 1986; Hemborg, 1983; Kipper, 1984; McGill, 1987; Sihvonen, 1988; Zetterberg, 1987). An overlooked muscle group that is anatomically positioned to assist in lifting is the hip extensors: gluteus maximus muscles, gluteus medius muscles, and the hamstring muscles (Gracovetsky, 1988). By virtue of their attachment to the thoracolumbar fascia, via the iliac bone, the hip extensors have an indirect connection to the spinous processes of the lumbar spine (Bogduk, 1984; Macintosh, 1987). Accordingly, activation of the hip extensor musculature could exert an influence on the lumbar spine.

Statement of the Problem

The problem is that although the hip extensor muscles have been believed to contribute to extension of the lumbar spine when performing a lift in a kyphotic posture, their function has not been analyzed. The purpose of this study was to determine the function of muscles anatomically related to the thoracolumbar fascia and lumbar spine (with particular emphasis on the hip extensor muscles) during a squat lift and to see what effect, if any, changing the lumbar posture has on that function. The research hypothesis was that squat lifting with the lumbar spine in a kyphotic position would result in a significant increase in the amount of myoelectric activity seen in the hip extensor muscles when compared to squat lifting with lumbar spine in a lordotic position.

Scope of the Study

Limitations

This study was limited by the following:

There was no control of the subjects activities, prior to the data collection.

Use of surface EMG electrodes to collect the data.

Delimitations

The study was delimited by the following:

Subjects to be used are males between the ages of 19 and 40.

Subjects are in a good state of health, with no recent history of low back pain with no recent history of low back pain, or knee pathology interfering with an ability to squat.

Variables

The independent variable was the style of lift. Each subject performed three squat lifts, using two different lumbar spine postures: 1) lumbar spine in kyphosis, and 2) lumbar spine in lordosis. The dependent variable was the amount of myoelectric activity recorded.

Assumptions

The following assumption were made:

That all subjects responded honestly on the questionnaire about present state of health and previous low back pain.

That a symmetrical lift produced equal EMG activity bilaterally (Cook, 1987; Seroussi, 1987; Sihvonen, 1988).

Significance of the Study

Low back pain is a common condition thought to affect up to 80% of the adult population in Western Europe and the United States (Andersson, 1981). Lifting is frequently cited as a cause of low back pain in working populations (Bigos, 1986). Prior research on lifting techniques has primarily centered on the role played by the trunk musculature (Andersson, 1977, 1976; Delitto, 1987; Ekholm, 1982; Hemborg, 1983; McGill, 1987; Zetterberg, 1987). This study investigates the function of the hip extensor musculature during a squat lift and the effect that two variations in the lumbar posture have on this function. This increased knowledge of muscle activity during a lift may lead to a greater understanding of the forces incurred by the lumbo-sacral spine during a lift. It is hoped that safer techniques of lifting may then be developed which will better protect the worker and decrease the incidence of low back pain in the work-place.

CHAPTER 2

LITERATURE REVIEW

In the United States and Western Europe low back pain has been shown to be a leading cause of disability and lost time at work especially in occupations involving manual labor (Andersson, 1981). Because of the cost of these injuries in medical expense and disability payments there has been a great deal of interest and study of manual lifting (Andersson, 1985, 1977, 1976; Aspden, 1989; Bush-Joseph, 1988; Cook, 1987; Delitto, 1987; Ekholm, 1982; Freivalds, 1984; Gagnon, 1985; Gracovetsky, 1988, 1985, 1981; Hart, 1987; Hemborg, 1983; Jonsson, 1985; Kippers, 1989; McGill, 1987, 1986, 1985; Ortengren, 1981, Seroussi, 1987; Troup, 1977; Zetterberg, 1987). Despite this work there is a still disagreement over their back support mechanism of proper lifting techniques and the forces sustained by the lumbar spine while lifting. This chapter will briefly review lumbar support mechanisms, anatomy of the thoracolumbar fascia and squat lifting.

Support Mechanisms

Two postulated mechanisms for support of the lumbar spine while lifting are intra-abdominal pressure, and the posterior ligamentous system. Each system has it supporters and detractors but neither theory has been fully validated experimentally, nor has either been totally refuted.

Intra-abdominal Pressure

The intra-abdominal pressure mechanism of reducing compressive forces on the spine during lifting was first proposed by Bartelink in 1957. A rise in intra-abdominal pressure as measured with a gastric balloon was noted when subjects lifted. Andersson (1976) determined that the intra-abdominal pressure increased as the load increased or as the amount of forward bending of the trunk increased. The rise in intra-abdominal pressure coincided with an increase in EMG activity of the transversus abdominis and internal oblique muscles. It was concluded that contraction of the abdominal muscles in the presence of a closed glottis produced a rise in the intra-abdominal pressure creating a "balloon" in front of the vertebral column that resisted compression and gave an anti-flexion moment to the lumbar spine (Bartelink, 1957, Andersson, 1976). This anti-flexion moment assisted the extensor muscles of the spine. Therefore, the extensor muscles did not have to contract as hard and compression on the spine secondary to erector spinae muscle contraction was decreased.

The concept of intra-abdominal pressure decreasing compression through creation of an anti-flexion moment is not universally accepted. Objections have been raised on a theoretical level. Calculations of the intra-abdominal force needed to provide the necessary upward force on the thorax exceed the systolic aortic blood pressure (Gracovetsky, 1985). If these pressures were developed, they could only be sustained for a short period of time to avoid compromising lower extremity circulation. The calculated force of contraction of the abdominal muscles necessary to generate this tension exceeds the maximum tension the muscles could produce (Gracovetsky, 1985). Additionally, any increase in intra-abdominal pressure produced by abdominal muscle activity would also produce a flexion moment of the trunk (Gracovetsky, 1985; McGill, 1987; and Macintosh, 1987). To offset the increased flexion moment requires increased erector spinae muscle activity, resulting in an increase in spinal compression (Gracovetsky, 1985; McGill, 1987; and Macintosh, 1987). Aspden calculated that the intra-abdominal pressure acting on the convex surface of a lordotic lumbar spine results in an increase in discal pressure and increased compression on the tissues of the lumbar spine (Aspden, 1989). His calculations show that this compression results in increased stability and is within safe limits for the tissues of the lumbar spine (Aspden, 1989).

Recent evidence has indicated that the role of intra-abdominal pressure in decreasing compression on the lumbar spine may be overrated (McGill, 1987, 1986; Nachemson, 1986). McGill (1987) cited studies showing that laborers lifting with increased intra-abdominal pressure had increased rates of low back injury. If increased intra-abdominal pressure actually protected the spine then subjects should have exhibited decreased injury rates. Increased intra-abdominal pressure, due to a valsalva maneuver, resulted in increased disc compression, not decreased (Nachemson, 1986). Andersson (1976) found that when people lifted and consciously tensed their abdominal muscles, the compression on the spine did not decrease. Hemborg (1982) found intra-abdominal pressure to be load specific. Training of the abdominal musculature resulted in increased abdominal muscle strength but not in increased intra-abdominal pressure (Hemborg, 1982, Macintosh, 1987). McGill (1990) observed increased intra-abdominal pressure during sit-ups while the lumbar spine was flexing. However, according to proponents of the intra-abdominal pressure theory, increase in intra-abdominal pressure was thought to inhibit flexion of the lumbar spine during lifting.

Posterior Ligamentous System

The role of the posterior ligamentous system and thoracolumbar fascia in the support of the lumbar spine has received substantial attention (Bogduk, 1984; Gracovetsky, 1981, Macintosh, 1987). This theory called for the transmission of the power of the hip extensor muscles through the lumbar spine to the trunk and eventually to the arms by way of the posterior ligamentous system and thoracolumbar fascia (Gracovetsky, 1988; Bogduk, 1987). A brief review of the anatomy of the thoracolumbar fascia will assist in the understanding of these functions.

The thoracolumbar fascia is comprised of three layers, anterior, middle and posterior (fig. 1) (Macintosh, 1987). These layers envelop the muscles of the lumbar spine and separate them into three compartments (Bogduk, 1987). The anterior layer of thoracolumbar fascia arises from the anterior surface of the lumbar transverse processes, covers the anterior surface of the quadratus lumborum and attaches laterally at the lateral raphe with the other layers of the thoracolumbar fascia (Bogduk, 1984; 1987; Macintosh, 1987)

The middle layer of thoracolumbar fascia arises from tips of the lumbar transverse processes and lies posterior to the quadratus lumborum (Bogduk, 1984; 1987; Macintosh, 1987).

Laterally, the transversus abdominis takes its origin from middle layer.

The posterior layer of thoracolumbar fascia arises from lumbar spinous processes and covers the erector spinae muscles (Bogduk, 1984; Macintosh, 1987). It attaches laterally, blending with the other layers of the thoracolumbar fascia, along the lateral border of the iliocostalis lumborum and forms a dense raphe (Bogduk 1984; 1987). This has been termed the 'lateral raphe' (Bogduk, 1984). The thoracolumbar fascia has a cross-hatched appearance because it consists of two laminae, superficial and deep, which are fused together and form a network of obliquely crossing fibers extending from the lateral raphe to the midline (Bogduk, 1984). The superficial lamina has fibers orientated caudomedially and the deep lamina has fibers oriented caudolaterally (Bogduk,1984; Macintosh, 1987).

The superficial lamina fibers provide the latissimus dorsi with an attachment to the spinous processes of the vertebral column (Bogduk,1984). Contraction of the latissimus dorsi exerts an upward and lateral force on the upper lumbar vertebrae (Bogduk, 1984). On the lower lumbar vertebrae the force is lessened because the aponeurosis of the latissimus dorsi is fused with the lateral raphe (Bogduk, 1984). This spreads the force through the lateral raphe to the iliac crest (Bogduk, 1984).

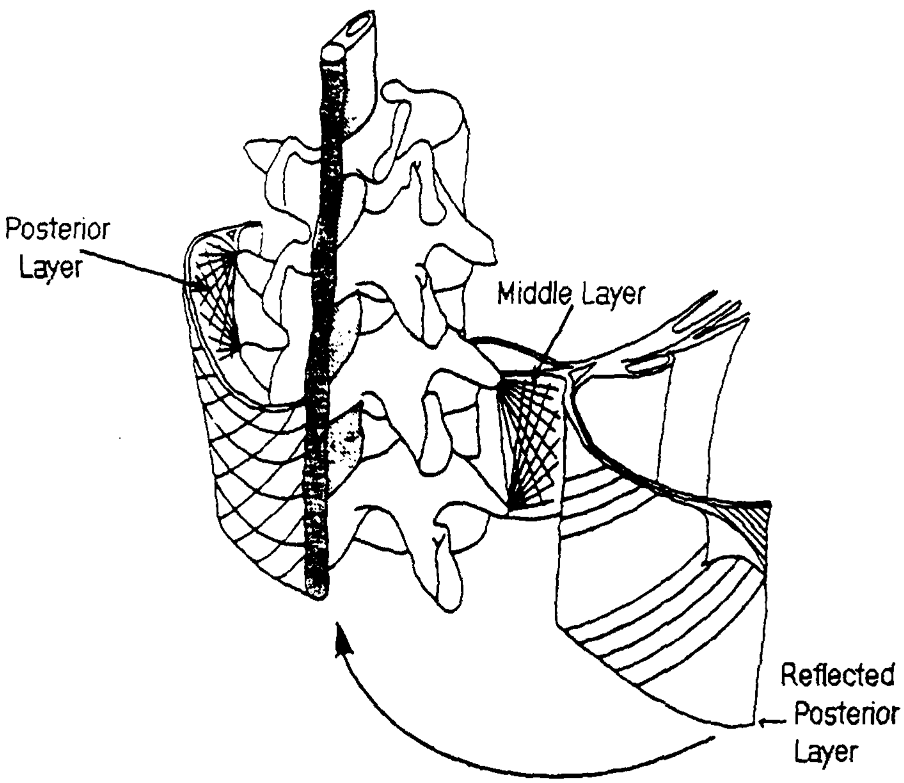

Figure 1. The thoracolumbar fascia. The posterior layer is comprised of separate laminae running in different directions, giving a crosshatched appearance. (Reprinted from Spine, 12, pg. 502).

The deep lamina of the posterior layer serve as retinacular fibers and as accessory ligaments (Bogduk, 1984). The fibers from the L_2-L_3 spinous processes fuse with the middle layer of the thoracolumbar fascia forms a retinaculum surrounding the erector spinae muscles (Bogduk, 1984). The fibers from the spinous processes of L_4-L_5 connect to the iliac crest, forming a retinaculum over the multifidus and the lower portion of the longissimus thoracis (Bogduk, 1984). The fibers from L_4-L_5 because of their bony attachments can also serve as accessory ligaments (Bogduk, 1984).

The superficial and deep laminae from the posterior layer join together at the lateral raphe along with middle layer of the thoracolumbar fascia and the transversus abdominis, whose fibers arise from the middle layer (Bogduk, 1987). This provides the transversus abdominis with an indirect connection the lumbar spinous processes through the posterior layer of the thoracolumbar fascia (Bogduk, 1987).

The posterior ligamentous mechanism can act either passively or actively (Gracovetsky 1985; 1981). It acts passively when the spine is flexed and the ligaments are taut. Extension of the hip causes posterior rotation of the pelvis (Gracovetsky, 1988; Bogduk, 1987). The posterior rotation of the pelvis is transmitted to the lumbar spine through the lumbosacral joints, the L_5-S_1 interspinous ligament, the iliolumbar ligaments, and the thoracolumbar fascia (Bogduk, 1987). It is succeedingly transmitted up the spine to the thorax via the posterior elements and rotates the thorax posteriorly producing a lift (Bogduk, 1987). This passive mechanism is possible only as long as the lumbar spine is in a flexed position and the ligaments are taut (Bogduk, 1987). When the spine extends, the ligaments relax and can no longer transmit forces to the thorax (Bogduk, 1987). This drawback is compensated by another mechanism that acts independently of spinal flexion angle and operates in concert with the posterior ligaments (Bogduk, 1987; Gracovetsky, 1985; 1981). The posterior layer of the thoracolumbar fascia provides the basis of this mechanism (Bogduk, 1987). Because of the thoracolumbar fascia's muscle attachments and its role as a ligament the fascia is thought to be a major support mechanism for lifting regardless of the lumbar posture adopted (Delitto, 1987; Gracovetsky, 1981; McGill, 1985). There are thought to be three methods by which the posterior layer of the thoracolumbar fascia can stabilize the lumbar spine and assist in lifting (Bogduk, 1987; 1984). The first function is the aforementioned passive ligamentous role of the deep lamina (Bodguk, 1987). The deep lamina provides a direct connection of the L_4 - L_5 spinous processes to the ilium. The ligaments are tense when the lumbar spine is flexed (Bogduk, 1987). A second function of the thoracolumbar fascia is derived from the crosshatching fibers of the two lamina and the attachments of the lateral raphe and transversus abdominis (Bogduk, 1987). The divergent direction of the fibers produces a pattern of overlapping triangles with apex in the lateral raphe and base spanning two vertebral levels in the midline (Bogduk, 1984). A lateral tension applied to a given point of the lateral raphe will spread out over a triangular area and produce an extension moment at the midline (Bogduk, 1984; 1987). Contraction of the transversus abdominis acting through its attachment at the lateral raphe can produce an anti-flexion moment of the lumbar spine (Bogduk, 1987). The third function of the thoracolumbar fascia arises from the of the posterior layer's retinacular structure (Bogduk, 1987). This layer is relatively indistensible and resists expansion of the lumbar muscles as they contract (Bogduk, 1987; Gracovetsky, 1977). An increased tension in the fascia's posterior layer will result, augmenting the anti-flexion properties of the thoracolumbar fascia (Bogduk, 1987). This has been termed the 'hydraulic amplifier mechanism' (Gracovetsky, 1987).

The chief advantage cited for the posterior ligamentous theory is that the thoracolumbar fascia has the greatest mechanical advantage of all the tissues of the lumbar spine that provide an anti-flexion moment (Sullivan, 1989). Because of this the thoracolumbar fascia produces the least amount of compressive force on the lumbar spine (Gracovetsky, 1985).

Recent research has identified problems with the thoracolumbar fascial model of the lumbar spine (Bogduk, 1984; Macintosh, 1987; McGill, 1987). The thoracolumbar fascia, though anatomically capable of transforming the lateral pull of the abdominal muscles into an extensor moment on the lumbar spine, does not possess muscle fibers of sufficient number or suitably arranged mass to exert a significant anti-flexion moment (Bogduk, 1984; McGill, 1987; 1986; Macintosh, 1987).

Stoop Lift vs. Squat Lift

In addition to examining the support mechanisms of the lumbar spine investigators have been studying the most efficient and safest method of lifting (Andersson, 1977, 1976; Delitto, 1987; Ekholm, 1982; Hart, 1986; McGill, 1987, 1986, 1985; Ortengren, 1981; Seroussi, 1987; Troup, 1977). The squat lift is considered to be a much safer lift than the stoop lift for the following reasons: 1) the center of gravity of the load is held closer to the body decreasing the spinal flexion moment, 2) early onset of the erector spinae muscle activity protects the inert structures, 3) leg muscles are more active to assist in the lift, and 4) horizontal movement of the weight can be initiated by the body (Delitto, 1987). The squat lift can be performed with the lumbar spine in either a kyphotic or lordotic posture. Advocates exist for both postures (Gracovetsky, 1981; Sullivan, 1989). The advantages of the stoop lift are: 1) it requires less energy expenditure than the squat lift, 2) it decreases compression on the lumbar spine (Gracovetsky, 1981; Sullivan, 1989).

Kyphosis

Advocates of lifting with the lumbar spine in a kyphotic position believe it is a more efficient system and decreases compression on the lumbar spine (Gracovetsky, 1988, 1985, 1981). Less electrical activity is recorded from the erector spinae musculature when lifting with the lumbar spine in a kyphosis (Delitto, 1987; Hart 1986). This is especially true at the start of the lift where little or no activity is seen in the erector spinae musculature (Andersson, 1977, 1976; Kippers, 1984). The decreased activity means that inert structures are used almost exclusively early in the lift and it is not until the later stages that the muscles take over and complete the lift (Hart, 1986). One explanation for the decreased activity of the erector spinae is that the kyphosis puts the erector spinae in a more lengthened and efficient position which decreases the need for high levels of activity (Sullivan, 1989). The decreased activity results in decreased compression on the posterior elements of the spine (cited by Delitto, 1987). Lifting with a kyphosis utilizes ligaments possessing longer moment arms than the muscles (Gracovetsky, 1988, 1985, 1981). The increased efficiency results in a decrease in compression on the spine (Gracovetsky, 1988, 1985, 1981).

When lifting with the lumbar spine in kyphosis the extension of the spine is thought to be accomplished by muscle action through the use of the thoracolumbar fascia mechanism (Gracovetsky, 1988, 1985, 1981) The thoracolumbar fascia by nature of its attachment to the spinous processes, lateral raphe, latissimus dorsi and iliac bone is ideally positioned to extend the spine from the flexed position (Bogduk, 1987, 1984; Gracovetsky, 1988, 1985, 1981). However, the angle of insertion of the latissimus dorsi and abdominal muscles onto the thoracolumbar fascia the activity and mass of these muscles is not great enough to provide a sufficient extension moment to the lumbar spine (Bogduk, 1984; McGill, 1987, 1986; Macintosh, 1987). The hip extensor muscles are also anatomically positioned to extend the trunk. The gluteus maximus, and hamstrings along with the erector spinae muscles are the prime mover muscles in trunk flexion and extension in an upright subject (Carlsoo, 1961; Gracovetsky, 1988; Tanii, 1985). During forward flexion of the trunk the hamstring muscles display myo-electric activity throughout the range of motion. The gluteus maximus becomes active near the angle of maximum trunk flexion (Carlsoo, 1961; Portnoy, 1958; Tanii, 1985). Extension from the fully flexed position finds myo-electric activity in both the hamstrings and gluteus maximus

(Carlsoo, 1961; Portnoy, 1958). Thus, the hamstrings are active throughout trunk flexion/extension with the gluteus maximus active when more power is required (Joseph, 1958).

Lordosis

Proponents of lifting with the lumbar spine in a lordotic position contend a decreased stress is placed on the posterior elements of the lumbar spine (Hart, 1986). Others contend that there is actually increased compression (Andersson, 1976; Aspden, 1989; Gracovetsky, 1988, 1985, 1981). Aspden (1989) reports that along with increased erector spinae muscle activity there is increased compression but, the compression is well within the tissues ability to withstand. This increased erector spinae activity along with increased intra-abdominal pressure recorded when lifting with the lumbar spine in a lordosis, prestresses the spinal tissue giving increased stability to the spine and protection to the inert ligamentous structures. (Aspden, 1989; Delitto, 1987; Hart, 1986).

Summary of Literature Review

Regardless of style of lifting technique advocated, researchers agree that the erector spinae muscles are much more active when the spine is in a lordotic position (Delitto, 1987; Hart 1986). With increasing trunk flexion angle the electrical activity of the erector spinae decreases until a position of electrical silence is reached when the spine is in about 90% of maximal trunk flexion. Because of the muscular silence the weight of the trunk is borne passively on the posterior ligamentous system (Kipper, 1984). When extending from a flexed position, it is not until late in the motion that the erector spinae EMG activity increases back to the EMG activity level present early in a lordotic position (Hart 1986; Kipper, 1984).

Early extension of the spine from the fully flexed position is thought to be accomplished by muscle contraction through the use of the posterior ligamentous system (Gracovetsky, 1988, 1985, 1981). It is still not entirely certain which muscles are controlling this mechanism. Some believe that the abdominal muscles and the latissimus dorsi are the muscles responsible (Gracovetsky, 1988, 1985, 1981). However, the myo-electric activity seen in the abdominals and latissimus dorsi does not imply sufficient strength to extend the spine given their attachments (McGill 1987, 1986; Macintosh, 1987). The hip extensor muscles are also anatomically positioned to move the trunk by acting through the ilium, an indirect connection to the thoracolumbar fascia.

Posture of the lumbar spine exerts an influence over the electrical activity of the erector spinae muscles when using a squat lift (Delitto, 1987; Hart, 1986). Greater myoelectrical activity is seen in the erector spinae muscles when the lumbar spine is in a lordotic posture versus a kyphotic posture (Delitto, 1987; Hart, 1986). Since the hip extensor muscles can control trunk flexion and extension, they should demonstrate increased electrical activity when lifting in a kyphotic position, if the posterior ligamentous system is involved.

CHAPTER 3

METHOD

This chapter will review the selection of the subjects, the instrumentation used in this study, and the methodology of data collection and analysis.

The Subjects

The Selection of Subjects

Seventeen healthy male subjects ranging in age from 20 to 38 years ($\bar{X}$ = 26.94 years). Each subject answered a questionnaire about present status of health and injury. Subjects were excluded from the study for the following reasons:

1) History of back pain or trauma to the low back within the last six months.
2) Knee pathology interfering with an ability to squat.
3) Cardiac precautions.
4) Respiratory problems preventing exertion.

The experimental procedure was explained to each subject and all questions about the research were answered. Subjects then read and signed a consent form approved by the University of Kentucky's Human Studies Committee.

Description of Methods of Data Collection

Instrumentation

Electromyography. Bipolar silver-silver chloride surface electrodes[1], (.05cm in diameter, 2 cm apart), and on-site preamplifiers were used in this study. Electromyographic signals were amplified[2] and recorded by a micro-computer after analog to digital conversion[3], at a sampling rate of 1000 Hz.

Lifting Apparatus. The subjects lifted a plastic crate (28 cm high, 33 cm deep and 33 cm wide), weighing 157 N. The weight selected was in accordance with safe and acceptable limits set by the Industrial Labor Organization The lifting crate had holes for hand holds 25 cm above the floor allowing for consistent hand placement. Two reflective markers, (one on each side), were placed on the sides of the crate so that the movement could be followed throughout the lift.

Video Analysis System. A quantitative analysis of the lift was performed by high speed videography. The "Expert-

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1 Therapeutics Unlimited; D-100 preamplified electrodes; 2835 Friendship St; Iowa City, IA 52240

2 Ibid. Model # EMG-67 EMG Amplifier Processor

3 Data Translation, Inc.; Model # DT-2821-F-16SE; 100 Locke Dr.; Marlboro, MA 01752

Vision" system (Motion Analysis Corporation[4]) was used to extract kinematic data from raw video signals. The subjects were filmed by four phase-locked NAC[5] high-speed video cameras at 60 frames/second. The cameras run synchronously with the EMG recorded from the subject during the lift. Two cameras were placed in front of the subject, and two were placed behind the subject. The cameras were placed to insure that all reflective markers were in view of at least two cameras at all times. The points on the lifting crate were automatically identified by the Motion Analysis System and computer digitized on a Sun Workstation[6]. This information gave a mathematically generated three-dimensional record of the movement of the lifting crate.

Procedure

Electromyography. The skin was wiped with alcohol before application of the electromyographic electrodes. Only right side musculature was monitored as other researchers have shown that when lifting or carrying loads in the midline the myo-electric signals are symmetrical bilaterally (Cook, 1987;

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[4] Motion Analysis Corporation; 93 Stony Circle; Sana Rosa, CA; Software v. 2.01

[5] NAC Model #HVRB-2000; NAC Inc.; No. 2-7 Nishi-Azuba 1-chome; Minato-ku, Tokyo, Japan

[6] Sun Microsystems; Model # Sparc Station 330; 2550 Garcia Ave; Mountain View, CA 94043.

Seroussi, 1987; Sihvonen, 1988). All electrodes were applied in line with the direction of the muscle fibers. The location of the electrode were as follows (fig. 2):

1) Over the muscle belly of the erector spinae (ES) muscles horizontally aligned with the L^3-L^4 interspace, 4cm lateral to the midline.
2) Over the oblique abdominals (AO) muscles, posterior to the midway point of a line running vertically from the ASIS to the 12_{th} rib.
3) Over the rectus abdominis (RA) muscle, 2cm cranial and 2cm lateral to the umbilicus.
4) Over the gluteus maximus (GM) muscle, at the midway point on a line connecting the inferior lateral angle of the sacrum and greater trochanter.
5) Over the latissimus dorsi (LD) muscle, 5cm inferior and 3cm lateral to the inferior angle of the scapula.
6) Over the biceps femoris (BF) muscle, at the junction of its proximal two-third and distal one-third.
7) Over the semitendinosus (ST) muscle, midway between its insertion on the upper part of the tibia and its origin on the ischial tuberosity.

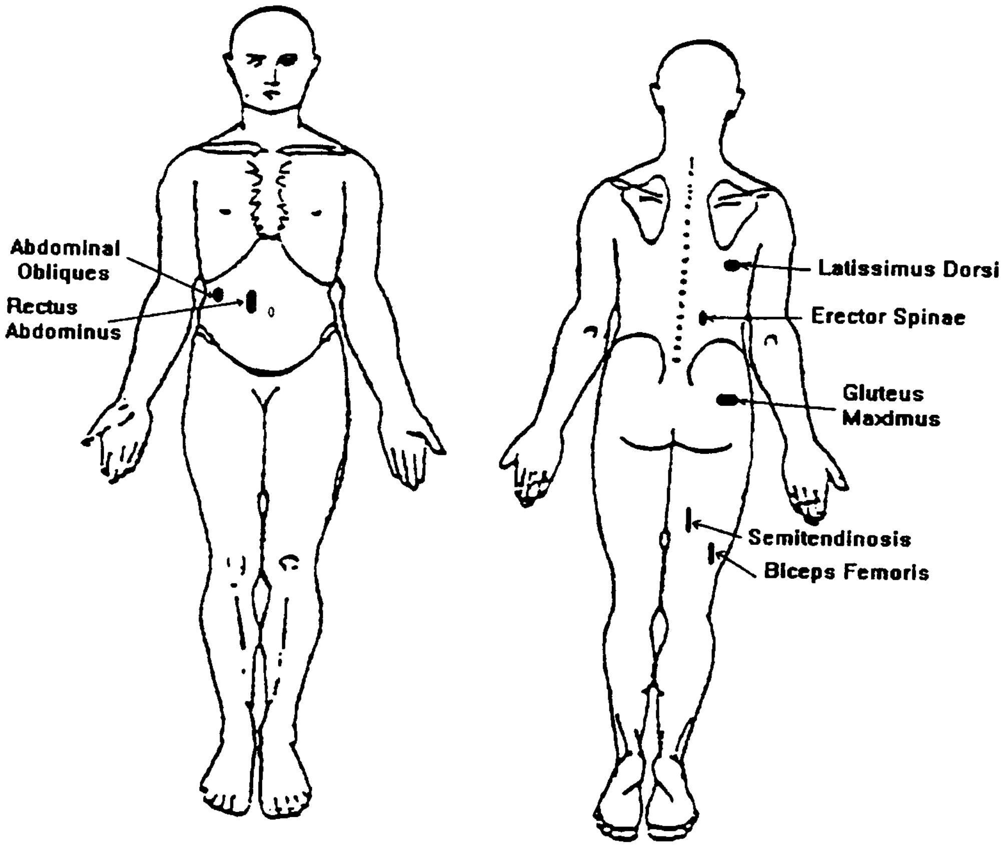

Figure 2. Placement of EMG electrodes.

A quiet EMG reading was taken for each muscle and recorded, then a maximal voluntary isometric contraction (MVIC) was elicited and recorded. From a pilot project performed on eight subjects the following positions were found to give the greatest EMG signals for maximal contraction:

1) Rectus Abdominis (RA). The subjects were positioned supine with hips and knees flexed 90° and lower leg supported on a chair. The subjects crossed their arms over their chest and attempted to flex their trunk while manual resistance was applied at the shoulders.
2) Abdominal Obliques (AO). Subjects lay supine with their hips flexed 90° and knees straight. The subjects attempted to rotate their lower trunk to the right while the tester applied manual resistance lateral side of the lower leg.
3) Erector Spinae (ES). The subjects lay prone with their arms at their sides. The subjects then arched their backs lifting their chest off of the table while the tester applied manual resistance to the back of the shoulders.
4) Latissimus Dorsi (LD). The subjects stood with their right arm in slight flexion and abduction. The

subjects attempted to extend and adduct the arm against maximal manual resistance.

5) Gluteus Maximus (GM). The subjects lay one-half way between prone and left side-lying. The right leg is brought into extension and abduction. The subject resists against the tester trying to move the leg into flexion and adduction.

6) Biceps Femoris (BF). Subject lies prone with right knee flexed 90°. The subject attempts to further flex the knee against resistance applied by the tester.

7) Semitendinosus (ST). Same as biceps femoris.

EMG analysis. All signals collected during the test underwent an analog to digital conversion at a frequency of 1000 hz. Based on the total time duration of the lift, determined through video analysis, the lift was normalized to a percentage of cycle and divided into four equal phases, each consisting of 25% of the total cycle. A customized software package[7] was used to calculate the average peak intensity for each muscle during each phase of the lift. Two methods were used to normalize the EMG signals recorded in this study. The EMG activity during the lift was expressed as: 1) as a percentage of the maximum volitional isometric contraction

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7 Asyst v. 2.1; Mcmillan Software Co.; 866 Third Ave.; New York, NY 10022

(figs. 3-4) (% MVIC) and 2) as a percentage of the maximum EMG activity recorded during the activity (figs. 5-6) (% MDA). The EMG activity values of three trials for the same condition were averaged.

Video Analysis. Prior to data collection for each subject the cameras and motion analysis system were calibrated according to manufacturers instructions[8] Reflective markers were used to define a space four feet wide by four feet long by eight feet high. All lifting was done within this defined space. Reflective markers were placed on the sides of the lifting crate and the reflective markers were tracked as they moved through space while the subjects performed the lifts. The computer assigned X and Y coordinates to the markers at each point in time. When two cameras have a marker in view the Z coördinates may be affixed to that marker. In this way a mathematical 3-dimensional construction of path of the markers can be constructed. The beginning and end points of the lift were determined through video analysis. The start of the lift was defined as the point where the vertical movement and vertical velocity of the box first moved in a positive direction. The end point of the lift was that point where the box vertical height reached a maximum and the velocity reached zero.

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[8] Motion Analysis Corporation; 93 Stony Circle; Sana Rosa, Ca. software v. 2.01

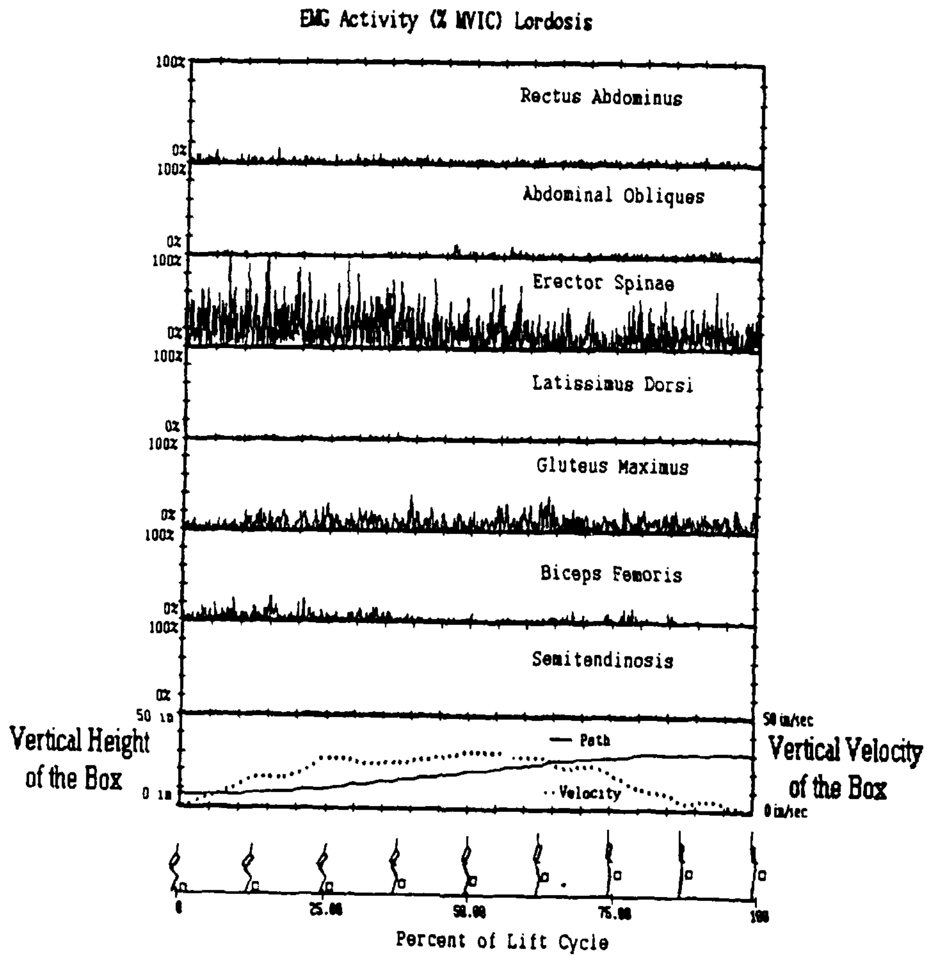

Figure 3. Plot of the EMG activity (% MVIC) recorded during a squat lift with the lumbar spine in lordosis.

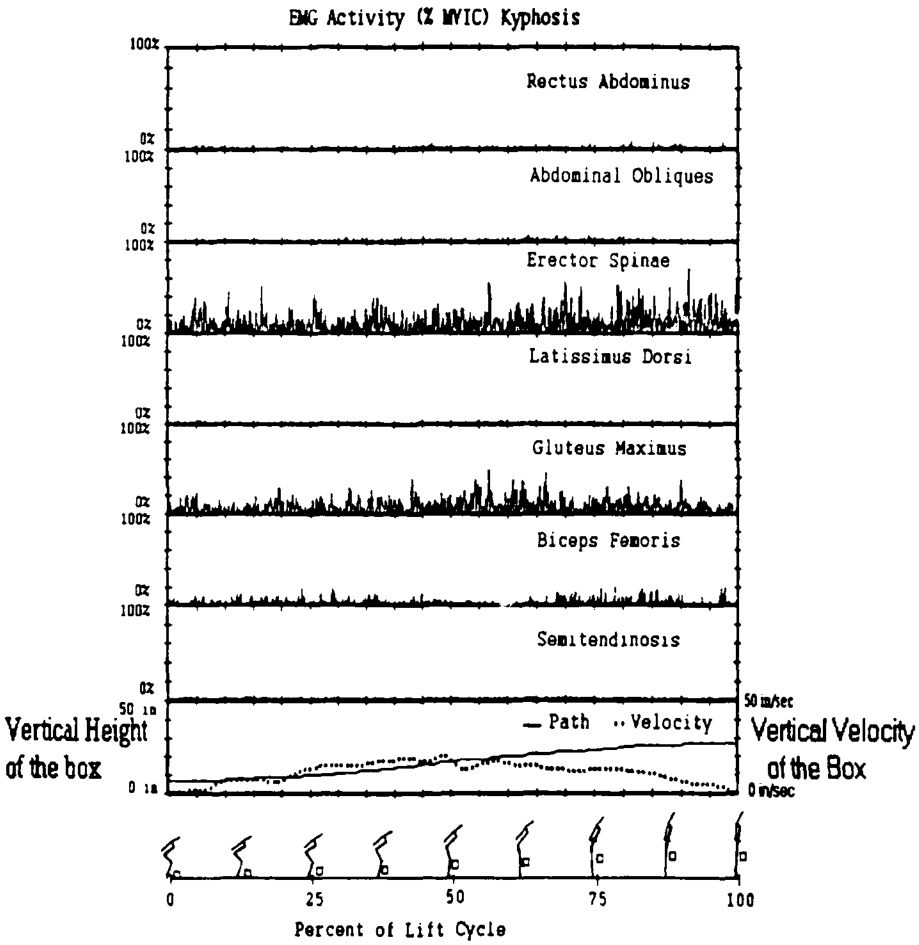

Figure 4. Plot of the EMG activity (% MVIC) recorded during a squat lift with the lumbar spine in kyphosis.

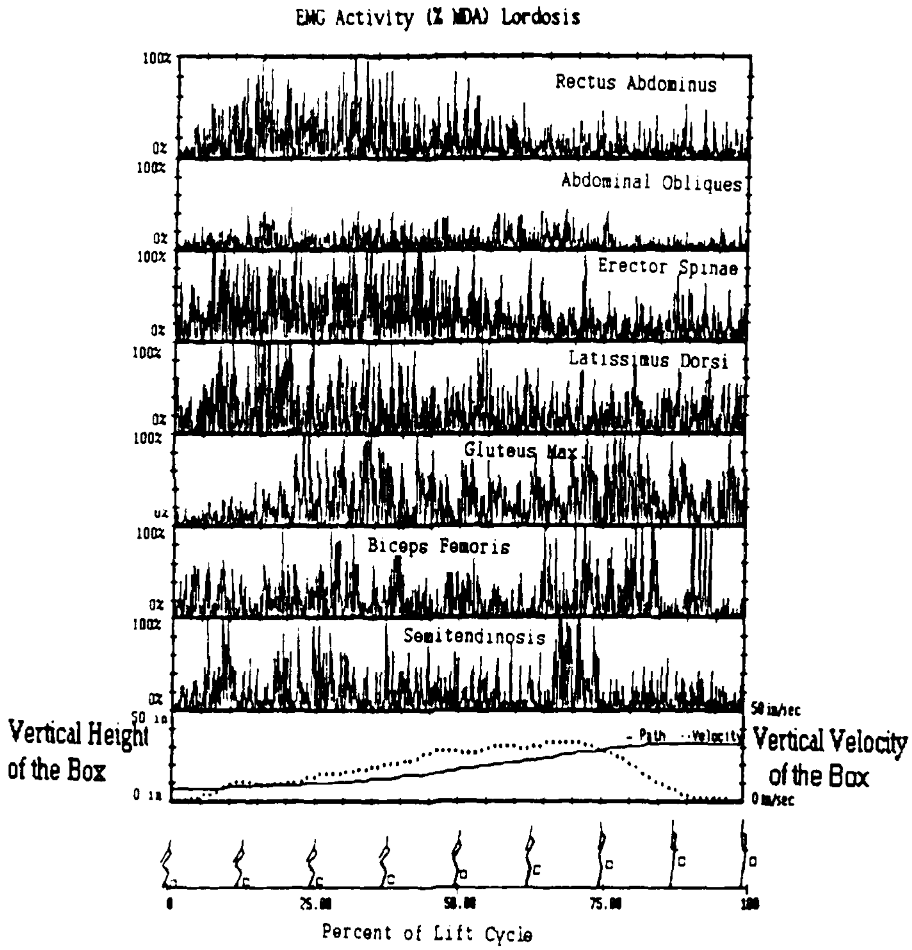

Figure 5. Plot of the EMG activity (% MDA) recorded during a squat lift with the lumbar spine in lordosis.

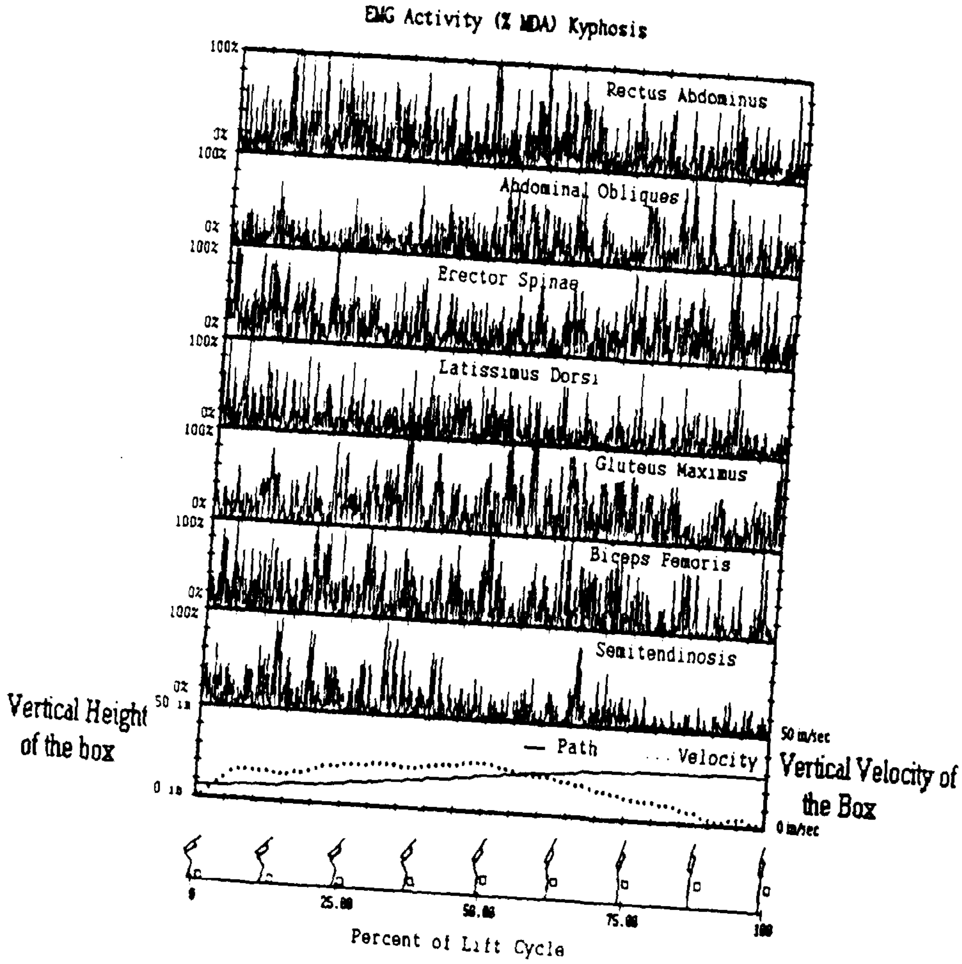

Figure 6. Plot of the EMG activity (% MDA) recorded during a squat lift with the lumbar spine in kyphosis.

Each subject performed both styles of lifts. The procedure for each type of lift was explained to the subject and the subjects were allowed to practice until the tester felt the lift was being executed properly and the subjects felt comfortable performing the lifts. A minimum of one minute rest was given between the lifts during the practice and testing sessions, to avoid fatigue. The order in which the lifts were performed was selected randomly for each subject. Subjects lifted at their preferred pace, completing three repetitions for each type of lift. Amount of lordosis/kyphosis at the start of the lift was determined through the use of a flexible ruler[9]. The technique of Hart and Rose modified such that L_3 was used as the top point of the curve instead of L_1 (Hart, 1986). The subject's lordosis was measured in the standing position and again when the subject assumed the squatting position, prior to lifting. For the lordotic lift the subjects would 'arch their low back' until the shape of the flexible ruler matched the shape measured with the subject standing. For the kyphotic lift the subject would 'flatten their low back' until the curve measured was straight or nearly straight, ensuring less lordosis in the starting position. The distance from the floor to the greater trochanter was measured with a metal ruler with the subject in a squat position to ensure consistent hip and knee flexion angles at the start of the

[9] The C-Thru Ruler Company; Bloomfield, CT, 06002

lift. The subject would begin each lift with the greater trochanter at the same height. All lifts were performed with the arms straight or nearly straight.

Data Reduction and Analysis

The lift was divided into four equal phases based on the total duration (as determined by video analysis). The EMG activity of the ES, RA, AO, GM, BF, ST, and LD was quantified by determining the average peak intensity during each phase of the lift (analysis by custom computer software package) and expressing this as a percentage of the peak intensity of a maximal contraction (% MVIC) (figs. 1, 2) and as a percentage of the maximum peak intensity occurring during the activity (% MDA) (figs. 3, 4). Average maximum peak amplitudes of the MVIC and MDA were calculated by a customized computer software package. The digitized signal was rectified and sorted by amplitude. The mean of the 50 highest amplitudes of the isometric test contractions was used to compute the MVIC and the mean of the 100 highest amplitudes of the actual lift was used to determine the MDA.

Statistics

A two-way analysis of variance (2 x 4) for repeated measures was performed to analyze the effect of the following factors on the amount of EMG activity:

1) Factor I - Style of lift (lordosis vs. kyphosis).
2) Factor II - Phase of the lift (first quarter vs. quarters two, three and four, second

quarter vs. quarters three and four and third quarter vs. fourth quarter).

Each muscle was analyzed separately. Results were considered significant at the level of $p < .05$.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter will present the results of the analysis and discuss differences found in the two lifting styles. The results of each method (% MVIC and % MDA) of analysis will be treated separately

Overview

Generally, a comparison of the EMG activity (% MVIC and % MDA) recorded in each phase of the lift and in each muscle in both the lordotic and kyphotic styles found more similarities than differences. All muscles tested showed differences ($p < .05$) between subjects and between phases within a lift (tabs. 1-14) except the BF muscle, and GM muscle, where a difference ($p<.05$) was not seen between the individual subjects, using % MDA analysis (tabs. 10, 12). A difference ($p<.05$) was found between the lordotic and kyphotic lifting styles (style) in only the erector spinae muscles, with % MVIC analysis, (tab. 6). Differences ($p<.05$) in the timing of EMG activity (phase vs style interaction) was found in the erector spinae muscle, % MVIC and % MDA, and the semitendinosus, % MDA (table 5,6 and 12). A more detailed analysis of each muscle follows.

Table 1. ANOVA Table - Rectus Abdominis (% MVIC)

Source	df	ss	ms	f ratio
Subject	16	121.26	7.58	56.94*
Style	1	0.03	0.03	0.26
Phase	3	6.37	2.12	15.95*
Phase vs Style	3	0.17	0.06	0.43
Error	112	14.91	0.13	
Total	135	142.74		

* $p < .05$

Table 2. ANOVA Table - Rectus Abdominis (% MDA)

Source	df	ss	ms	f ratio
Subject	16	923.70	57.73	3.21*
Style	1	37.41	37.41	2.08
Phase	3	3107.50	1035.83	57.54*
Phase vs Style	3	35.65	11.88	0.66
Error	112	2016.38	18.00	
Total	135	6120.63		

* $p < .05$

Table 3. ANOVA Table - Abdominal Obliques (% MVIC)

Source	df	ss	ms	f ratio
Subject	16	202.51	12.66	52.01*
Style	1	0.12	0.12	0.47
Phase	3	13.43	4.48	18.39*
Phase vs Style	3	0.13	0.04	0.18
Error	112	27.26	0.13	38.62
Total	135	243.44		

* $p < .05$

Table 4. ANOVA Table - Abdominal Obliques (% MDA)

Source	df	ss	ms	f ratio
Subject	16	923.70	57.73	3.21*
Style	1	37.41	37.41	2.08
Phase	3	3107.50	1035.83	57.54*
Phase vs Style	3	35.65	11.88	0.66
Error	112	2016.38	18.00	
Total	135	6120.63		

* $p < .05$

Table 5. ANOVA Table - Erector Spinae (% MVIC)

Source	df	ss	ms	f ratio
Subject	16	6978.78	436.17	20.75*
Style	1	17.18	17.18	0.82
Phase	3	2786.49	928.83	44.14*
Phase vs Style	3	558.56	186.19	8.85*
Error	112	2356.82	21.04	
Total	135	10350.02		

* $p < .05$

Table 6. ANOVA Table - Erector Spinae (% MDA)

Source	df	ss	ms	f ratio
Subject	16	1019.08	63.69	2.46*
Style	1	154.47	154.47	5.96*
Phase	3	6460.06	2153.35	83.11*
Phase vs Style	3	1263.76	421.25	26.26*
Error	112	2902.00	25.91	
Total	135	11799.37		

* $p < .05$

Table 7. ANOVA Table - Latissimus Dorsi (% MVIC)

Source	df	ss	ms	f
r a	t	i		o
Subject	16	322.65	20.17	37.12*
Style	1	0.77	0.77	1.43
Phase	3	78.83	26.28	

* $p < .05$

Table 8. ANOVA Table - Latissimus Dorsi (% MDA)

Source	df	ss	ms	f ratio
Subject	16	629.96	39.37	2.36*
Style	1	1.12	1.12	0.07
Phase	3	6832.84	2277.61	136.78*
Phase vs Style	3	98.44	32.81	1.97
Error	112	1864.92	16.65	
Total	135	9427.27		

* $p < .05$

Table 9. ANOVA Table - Gluteus Maximus (% MVIC)

Source	df	ss	ms	f ratio
Subject	16	2456.24	153.52	20.96*
Style	1	4.74	4.74	0.65
Phase	3	111.25	37.08	5.06*
Phase vs Style	3	22.07	7.36	1.00
Error	112	820.46	7.33	
Total	135	3414.78		

* $p < .05$

Table 10. ANOVA Table - Gluteus Maximus (% MDA)

Source	df	ss	ms	f ratio
Subject	16	906.07	56.63	1.24
Style	1	5.25	5.25	0.12
Phase	3	1793.72	597.91	13.12*
Phase vs Style	3	236.14	78.71	1.73
Error	112	5103.44	45.57	
Total	135	8044.62		

* $p < .05$

Table 11. ANOVA Table - Biceps Femoris (% MVIC)

Source	df	ss	ms	f ratio
Subject	16	2050.58	128.16	15.17*
Style	1	0.73	0.73	0.09
Phase	3	212.14	70.71	8.37*
Phase vs Style	3	64.18	21.39	2.53
Error	112	946.07	8.45	
Total	135	3273.70		

* $p < .05$

Table 12. ANOVA Table - Biceps Femoris (% MDA)

Source	df	ss	ms	f ratio
Subject	16	1238.54	77.41	1.11
Style	1	3.34	3.34	0.05
Phase	3	1088.19	362.73	5.20*
Phase vs Style	3	326.40	108.80	1.56
Error	112	7805.51	69.69	
Total	135	10461.99		

* $p < .05$

Table 13. ANOVA Table - Semitendinosus (% MVIC)

Source	df	ss	ms	f ratio
Subject	16	1290.64	80.66	37.98*
Style	1	3.11	3.11	1.46
Phase	3	18.73	6.24	2.94*
Phase vs Style	3	12.88	4.29	2.02
Error	112	2.12	0.02	
Total	135	1327.48		

* $p < .05$

Table 14. ANOVA Table - Semitendinosus (% MDA)

Source	df	ss	ms	f ratio
Subject	16	2616.93	163.56	4.60^{*}
Style	1	19.01	19.01	0.53
Phase	3	407.28	135.76	3.81^{*}
Phase vs Style	3	308.01	102.67	2.88^{*}
Error	112	3986.33	35.59	
Total	135	7337.55		

$* \ p < .05$

Results

Rectus Abdominal Muscles

% MVIC. The EMG activity of the rectus abdominis muscle was greatest early in the lift and decreased as the lift progressed (tab. 15; fig. 7). Differences ($p < .05$) were found between subjects and between quarters within a lift style (tab. 1). No difference ($p < .05$) were found when comparing EMG activity in each quarter between the lifting styles. The first quarter EMG activity was larger ($p<.05$) than quarters 2, 3 and 4 in the lordotic style of lifting (fig. 6). The second quarter EMG activity was greater ($p<.05$) than that found in the third or fourth quarter in the lordotic and kyphotic styles of lifting. No differences were found in EMG activity between quarters 1 and 2 of the kyphotic lift or between quarters 3 and 4 of either lifting style.

% MDA. There were differences ($p<.05$) between individual subjects and between quarters within a lift style (tab. 2). Quarter 1 is larger ($p<.05$) than quarter 2, quarter 3 or quarter 4 in the lordotic lift. In the kyphotic lift no difference was noted between quarter 1 and quarter 2, however quarter 1 and quarter 2 were larger ($p<.05$) than quarter 3 or quarter 4 (tab. 16, fig 8), this was also true in the lordotic lift as well. No difference in EMG activity was found between quarter 3 and quarter 4 in either lift style. Comparison of

Table 15. EMG Activity (% MVIC) - Rectus Abdominis

Style/Phase	N	MEAN	SEMEAN	MIN	MAX
Lordosis					
Quarter 1	17	2.05	0.30	0.55	5.11
Quarter 2	17	1.78	0.26	0.54	3.59
Quarter 3	17	1.53	0.21	0.43	3.11
Quarter 4	17	1.40	0.19	0.47	2.39
Kyphosis					
Quarter 1	17	1.98	0.28	0.46	4.27
Quarter 2	17	1.80	0.28	0.57	4.62
Quarter 3	17	1.52	0.22	0.52	3.56
Quarter 4	17	1.53	0.24	0.55	5.11

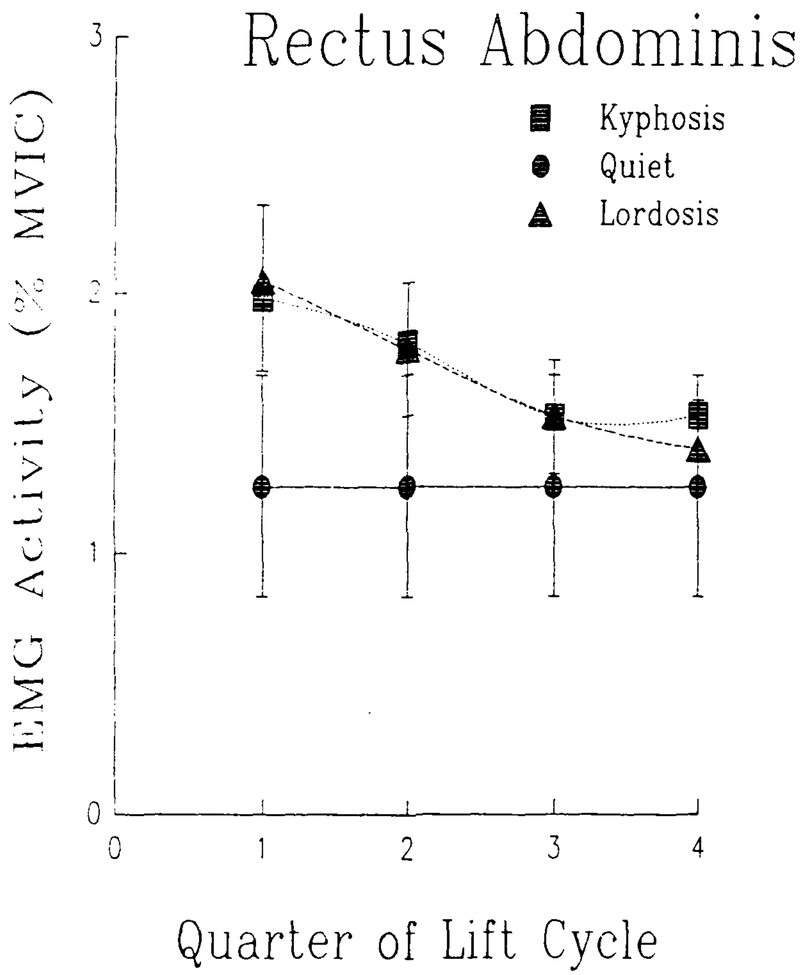

Figure 7. EMG Activity (% MVIC) Rectus Abdominis. Note the quiet file has nearly the same amplitude of activity as the lift.

Table 16. EMG Activity (% MDA) - Rectus Abdominis

Style/Phase	N	MEAN	SEMEAN	MIN	MAX
Lordosis					
Quarter 1	17	39.25	1.50	27.85	53.01
Quarter 2	17	33.50	1.17	24.64	41.57
Quarter 3	17	29.08	1.33	16.39	38.45
Quarter 4	17	27.37	1.10	17.97	34.99
Kyphosis					
Quarter 1	17	35.36	1.67	21.73	46.08
Quarter 2	17	33.13	1.62	21.12	48.83
Quarter 3	17	28.43	1.33	16.21	36.25
Quarter 4	17	27.82	1.45	15.10	39.13

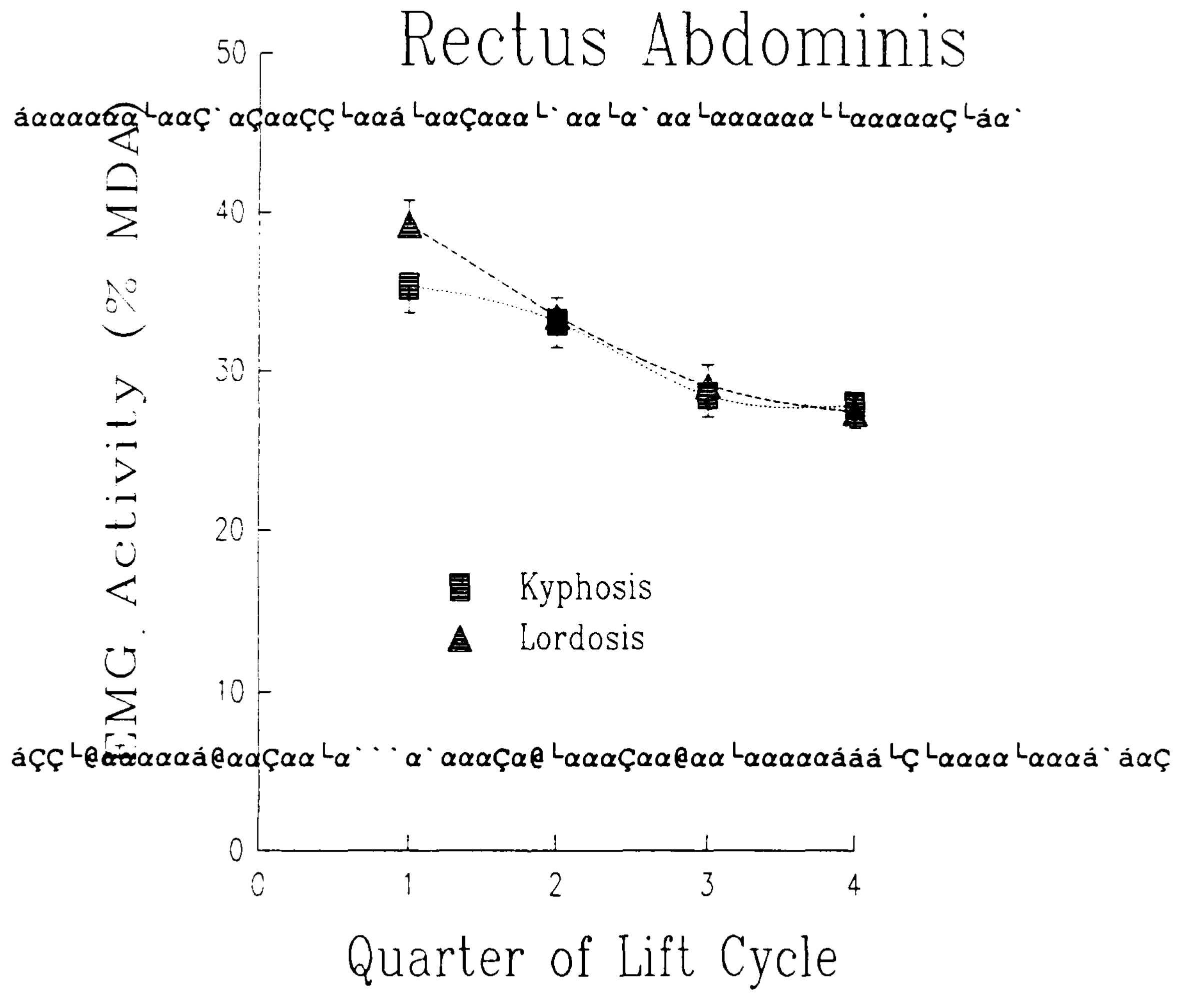

Figure 8. EMG Activity (% MDA) Abdominal Obliques.

EMG activity between the two lifting styles within a quarter found a difference only in the first quarter ($p<.05$) with the lordotic lift having the greater EMG activity (fig. 2).

Abdominal Oblique Muscles

% MVIC. Abdominal oblique EMG activity was greatest in the early phases of the lifts in both the lordotic and kyphotic styles of lifting (fig. 9; tab. 17). Differences ($p<.05$) were found between individual subjects and between quarters within a lifting style (tabs. 3). The EMG activity in the first quarter was larger ($p<.05$) than that found in quarters two, three and four in both the lordotic and kyphotic style of lifting. The EMG activity in quarter two was greater ($p < .05$) than that found in quarters three and four. No difference ($p<.05$) in EMG activity was found between quarters three and four in either style of lifting. No significant differences were noted in EMG activity when comparing lordotic vs. kyphotic postures in each quarter of the lift cycle.

% MDA. The results of the % MDA analysis were identical to that found in the % MVIC analysis. Differences ($p<.05$) were found between individual subjects and between quarters within a lifting style (tab. 4). The greatest EMG activity was found in the first quarter of the lift which decreased as the lift progressed regardless of lifting style (fig. 10, tab. 18). EMG activity in the first quarter was larger ($p<.05$)

Table 17. EMG Activity (% MVIC) - Abdominal Obliques

Style/Phase	N	MEAN	SEMEAN	MIN	MAX
Lordosis					
Quarter 1	17	2.41	0.45	0.75	7.78
Quarter 2	17	1.99	0.37	0.73	5.57
Quarter 3	17	1.63	0.28	0.58	4.29
Quarter 4	17	1.59	0.28	0.57	4.36
Kyphosis					
Quarter 1	17	2.33	0.33	0.84	5.82
Quarter 2	17	1.91	0.30	0.67	5.35
Quarter 3	17	1.68	0.29	0.57	5.04
Quarter 4	17	1.51	0.24	0.55	4.13

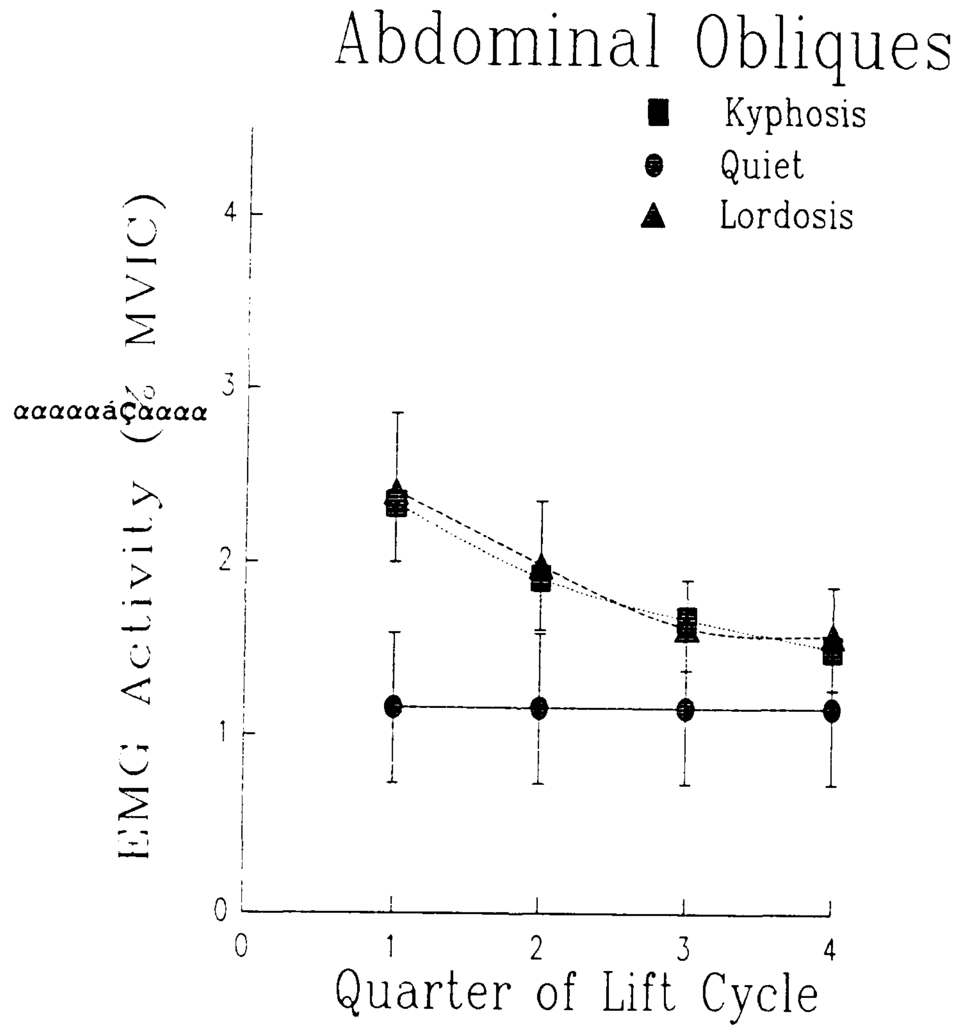

Figure 9. EMG Activity (% MVIC) Abdominal Obliques. Note that the quiet EMG amplitude is nearly the same as the amplitude during the lift.

Table 18. EMG Activity (% MDA) - Abdominal Obliques

Style/Phase	N	MEAN	SEMEAN	MIN	MAX
Lordosis					
Quarter 1	17	40.22	1.48	30.41	49.37
Quarter 2	17	33.26	1.04	26.25	40.47
Quarter 3	17	27.99	0.98	19.34	35.15
Quarter 4	17	26.96	0.64	20.20	30.14
Kyphosis					
Quarter 1	17	37.48	1.20	26.38	44.73
Quarter 2	17	32.38	0.97	22.63	38.27
Quarter 3	17	27.98	1.29	14.87	35.12
Quarter 4	17	26.39	1.46	13.30	35.51

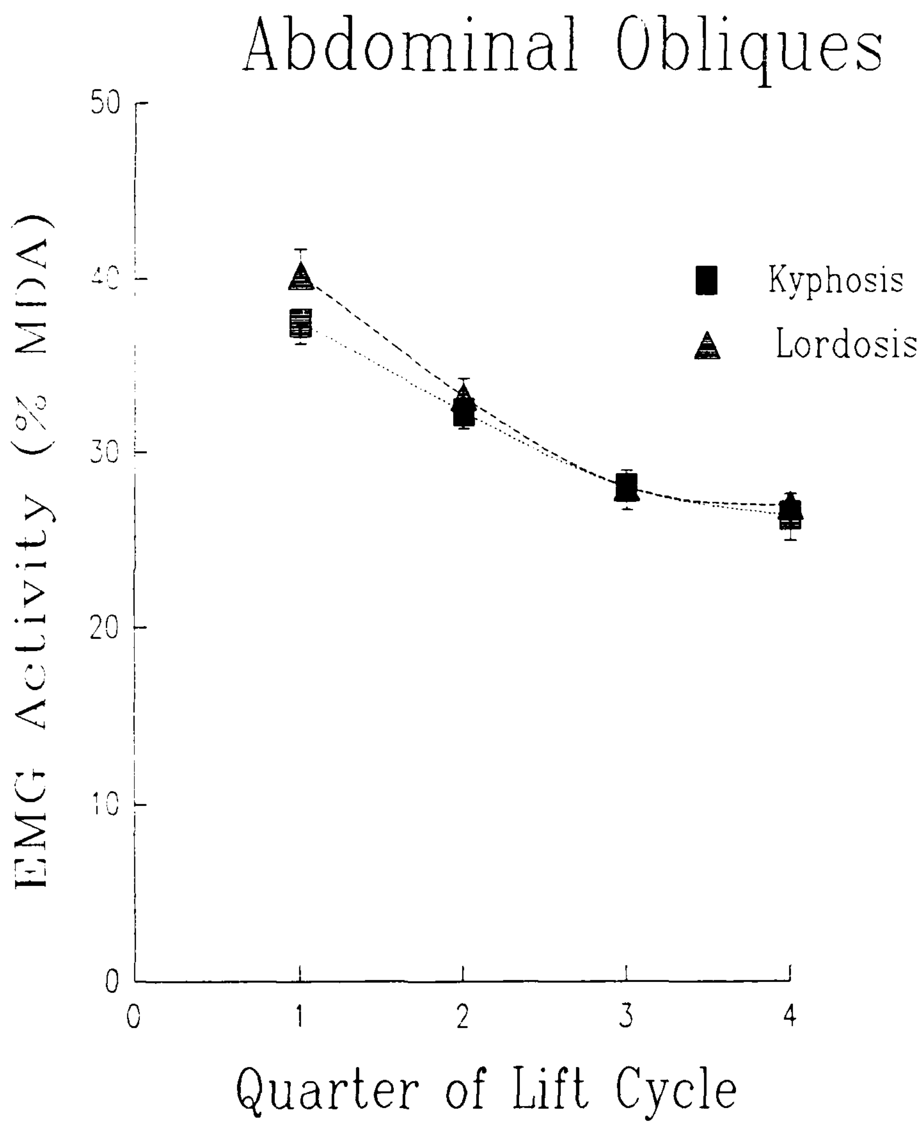

Figure 10. EMG Activity (% MDA) Abdominal Obliques.

than that found in quarter two, quarter three, or quarter four. EMG activity in quarter two was larger ($p<.05$) than that found in quarter three or quarter four. No difference was found in EMG activity between quarter 3 or quarter 4. No difference was found when comparing the EMG activity in each quarter of the lordotic lift against the EMG activity recorded in the same quarter of a kyphotic.

Erector Spinae Muscles

% MVIC. Erector spinae muscle EMG activity was greatest in the early stages of the lift and decreased throughout the lift in both styles of lifting. The level of EMG activity was greater in quarter one and less in quarter 4 in the lordotic lift (tab. 19; fig. 11). EMG activity in quarter one was greater ($p<.05$) than that found in quarter 2, quarter 3, or quarter 4 in both styles of lifts (tab. 19; fig. 11). The EMG activity in quarter two was also greater ($p < .05$) than that found in quarters three and four for both styles of lift. The EMG activity in the third quarter was larger ($p<.05$) than quarter four in both lifts. Difference were found in EMG activity between subjects, between quarters and with the timing of EMG activity in the two styles of lifting (style vs quarter) (tabs. 5, 6). Comparing the EMG activity between the two lifting styles in each quarter found the lordotic lift having more activity ($p<.05$) in the first quarter and less

Table 19. EMG Activity (% MVIC) - Erector Spinae

Style/Phase	N	MEAN	MEDIAN	SEMEAN	MIN	MAX
Lordosis						
Quarter 1	17	26.83	21.99	3.50	10.17	69.74
Quarter 2	17	20.89	17.75	2.40	7.73	47.01
Quarter 3	17	13.23	11.77	1.35	5.81	28.21
Quarter 4	17	10.10	9.26	0.88	4.41	15.85
Kyphosis						
Quarter 1	17	21.05	16.81	2.32	8.38	41.56
Quarter 2	17	17.80	16.25	1.96	7.69	38.51
Quarter 3	17	15.70	14.05	1.37	6.05	28.82
Quarter 4	17	13.83	14.51	1.52	5.64	30.69

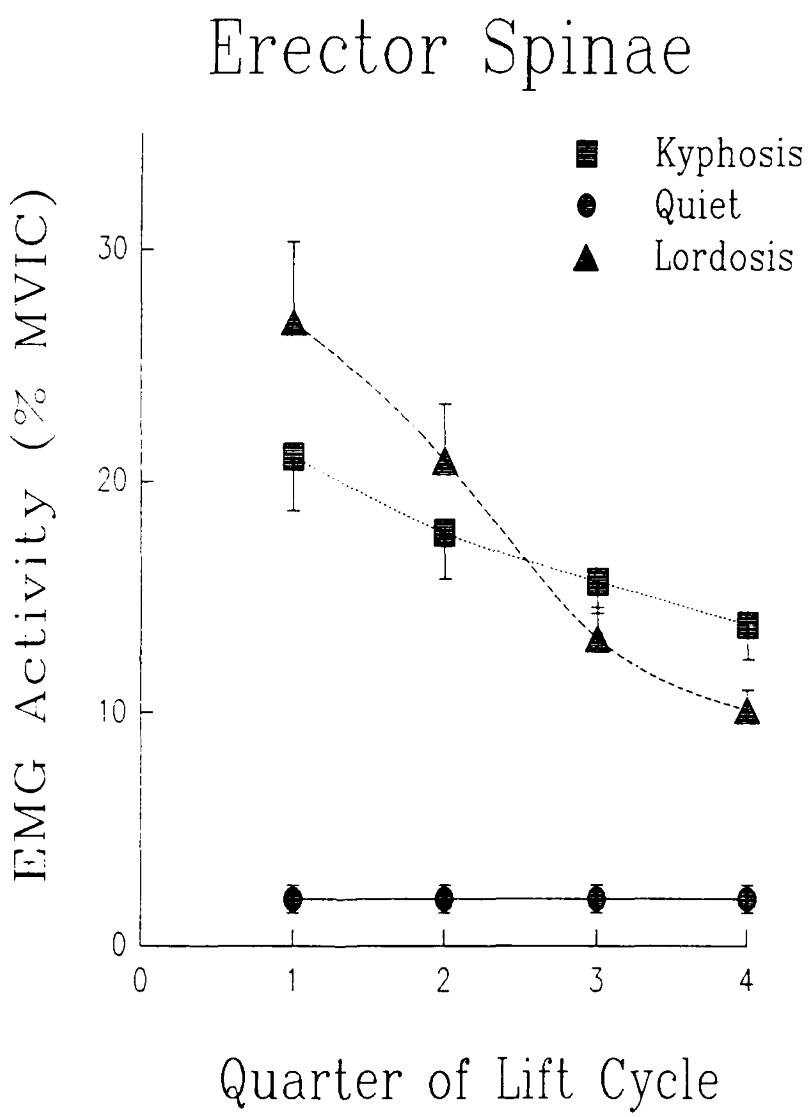

Figure 11. EMG Activity (% MVIC) - Erector Spinae. Note the difference in amplitude between the quiet file and lifting files.

activity in the fourth quarter than the kyphotic lift. No differences were found in quarter 3 or quarter four.

% MDA. Differences ($p<.05$) were found between individual subjects, between lifting styles in the same quarter, between quarters, and in the quarter-lift style interaction (tab. 6). The EMG activity in quarter one is greater ($p<.05$) than that found in quarter two, quarter three or quarter four in the lordotic and kyphotic styles of lifts (fig. 12). The activity in quarter two is also larger ($p<.05$) than that found in quarter three in the lordotic lift but not the kyphotic lift (fig. 6; tab. 20). Quarter two and three had greater EMG activity ($p<.05$) than that found in quarter four in both lifting styles (fig. 12; tab. 20). The EMG activity (% MDA) was greater ($p < .05$) during the third quarter in the kyphotic lift. Comparing EMG activity of the two lifting styles in the same quarter found differences ($p<.05$) in the first quarter, where the lordotic style was greater and in the third and fourth quarters where the kyphotic style had greater activity (fig 12; tab. 20).

Table 20. EMG Activity (% MDA) - Erector Spinae

Style/Phase	N	MEAN	SEMEAN	MIN	MAX
Lordosis					
Quarter 1	17	42.95	0.94	34.62	50.07
Quarter 2	17	33.89	1.01	26.07	39.43
Quarter 3	17	22.18	1.11	17.15	32.75
Quarter 4	17	17.70	1.30	9.82	31.34
Kyphosis					
Quarter 1	17	36.66	1.58	19.01	46.23
Quarter 2	17	32.84	1.25	18.31	39.89
Quarter 3	17	29.76	1.41	18.11	38.23
Quarter 4	17	25.98	1.88	13.51	40.38

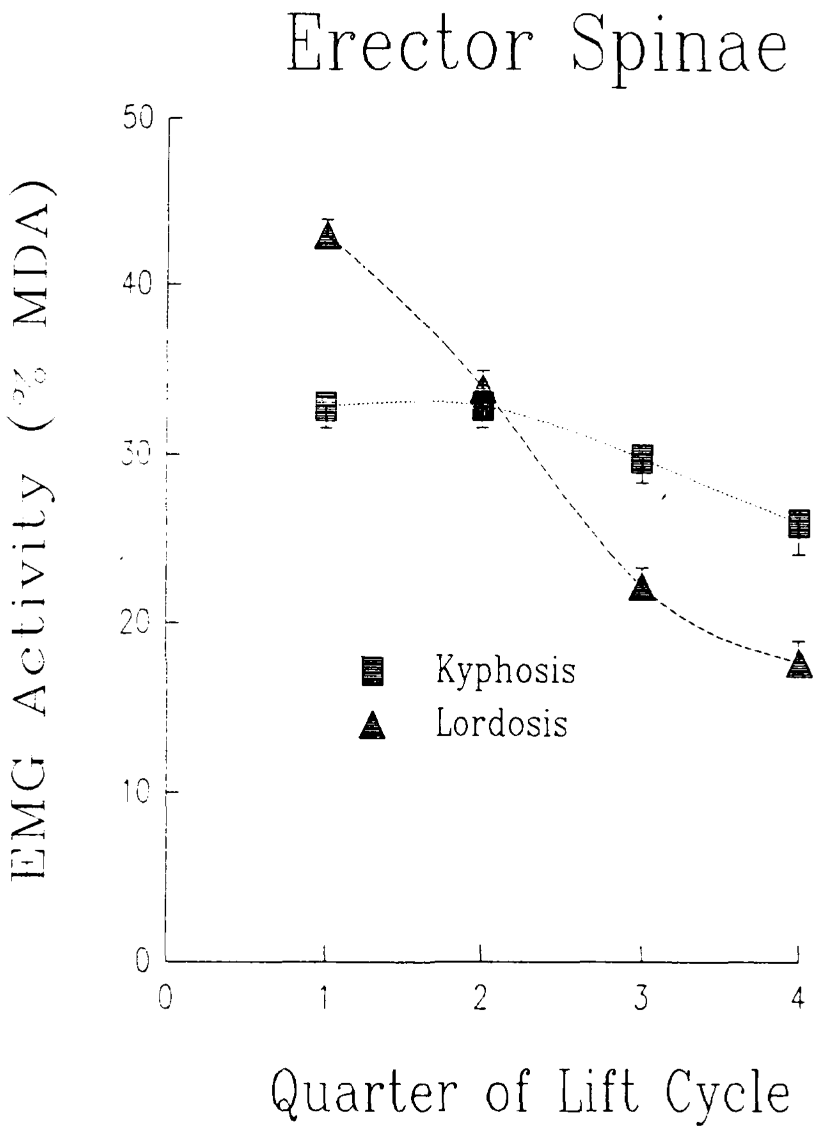

Figure 12. EMG Activity (% MDA) - Erector Spinae.

Latissimus Dorsi Muscle

% MVIC. EMG activity was greatest in the first quarter and decreased in each subsequent quarter (fig. 13; tab. 21). Differences ($p<.05$) were found between subjects and between quarters within a style of lifting (tab. 7). The first quarter had greater EMG activity than quarter two, quarter three or quarter four in both styles of lifting. Quarter two also had greater ($p<.05$) EMG activity than quarters three or four in both styles of lifting (fig. 13; tab. 21). No difference ($p<.05$) was found in the EMG activity between quarters three and four in either style of lifting (fig. 13; tab. 21). No differences were found when comparing the lordotic and kyphotic lift in each quarter (fig. 13; tab. 21).

% MDA. Followed a similar pattern to that reported for % MVIC. Differences ($p<.05$) were noted between subjects and between quarters within a lifting style. No differences were found between lifting styles, nor was a style-quarter interaction found. EMG activity was greatest in quarter one and decreased in each subsequent quarter. Quarter one had greater ($p<.05$) activity than that found in quarter two, quarter three or quarter four (fig. 14; tab. 22). Quarter two had higher activity ($p<.05$) than quarters three or four (fig. 14; tab. 22). Quarter three had more EMG activity than quarter four in the lordotic lift, but not in the kyphotic lift (fig. 14, tab. 22).

Table 21. EMG Activity (% MVIC) - Latissimus Dorsi

Style/Phase	N	MEAN	SEMEAN	MIN	MAX
Lordosis					
Quarter 1	17	4.27	0.57	1.38	9.57
Quarter 2	17	3.43	0.44	1.21	6.79
Quarter 3	17	2.48	0.32	0.72	5.45
Quarter 4	17	2.15	0.29	0.69	4.94
Kyphosis					
Quarter 1	17	3.99	0.58	1.09	10.76
Quarter 2	17	3.22	0.44	0.96	7.41
Quarter 3	17	2.42	0.31	0.89	5.37
Quarter 4	17	2.15	0.30	0.71	5.08

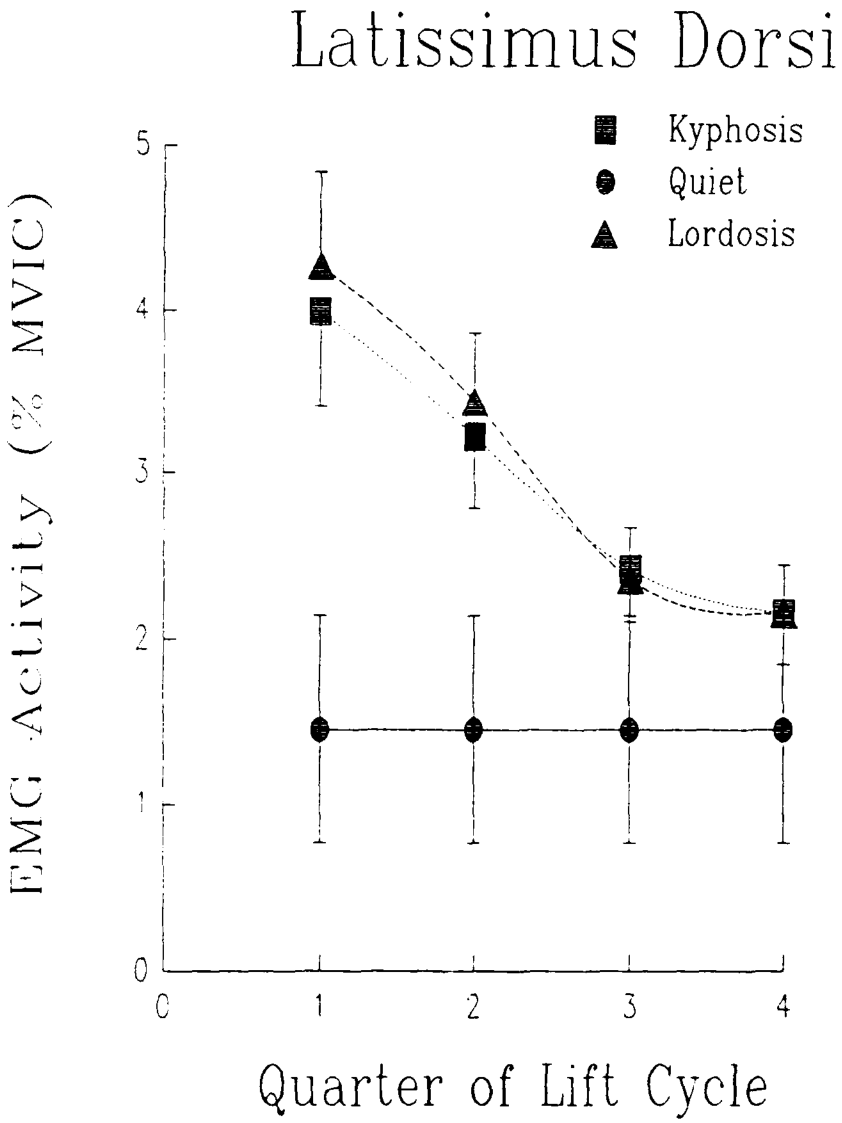

Figure 13. EMG Activity (% MVIC) - Latissimus Dorsi. Note that the EMG activity during the lift is the same as the quiet file in the latter stages.

Table 22. EMG Activity (% MDA) - Latissimus Dorsi

Style/Phase	N	MEAN	SEMEAN	MIN	MAX
Lordosis					
Quarter 1	17	40.94	1.30	30.87	49.29
Quarter 2	17	33.49	0.96	27.58	41.16
Quarter 3	17	23.92	0.85	17.41	31.11
Quarter 4	17	20.88	0.89	14.23	29.70
Kyphosis					
Quarter 1	17	38.26	1.58	24.58	48.35
Quarter 2	17	32.67	0.80	26.05	39.19
Quarter 3	17	25.10	0.84	16.08	32.26
Quarter 4	17	22.45	1.11	12.37	33.60

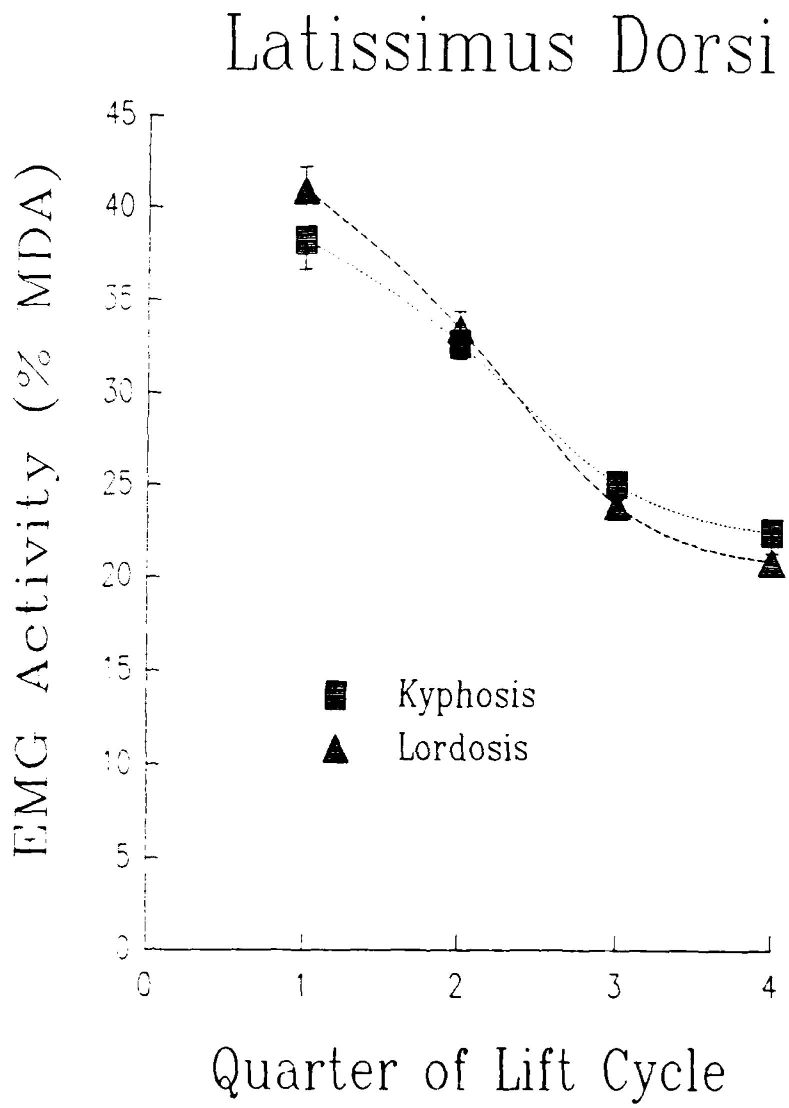

Figure 14. EMG Activity (% MDA) - Latissimus Dorsi.

Gluteus Maximus Muscle

% MVIC. Gluteus maximus muscle EMG activity reached a maximum intensity in quarters two and three and was less in quarter one and quarter four (tab. 23; fig. 15). Differences ($p<.05$) in EMG activity were found between subjects and between quarters within each style of lifting (tabs 15). No differences ($p<.05$) in EMG activity were seen when comparing the two styles of lifting against each other in each quarter (tabs. 9; figs. 15). EMG activity was greater ($p<.05$) in quarter two than quarter one in the lordotic and kyphotic lifts. Quarter three had greater EMG activity than quarter one in the lordotic lift but not in the kyphotic lift. No difference was noted in intensity of EMG activity between quarter one and quarter four or between quarters two and three in either the lordotic or kyphotic lift (fig. 15). Quarters two and three had greater ($p<.05$) EMG activity than quarter four in the kyphotic, but not in the lordotic lift (fig. 15).

% MDA. A similar pattern of EMG activity was seen using % MDA analysis. Differences were noted between subjects and quarters, but not between lifting styles (tab. 10). Quarter one had less ($p<.05$) EMG activity than quarters two and three in both styles of lifting and less than quarter four in the lordotic style (fig. 16; tab. 24). No differences ($p<.05$) were noted between quarters two and three in either lifting style, or between quarter two and four in the lordotic style

Table 23. EMG Activity (% MVIC) - Gluteus Maximus

Style/Phase	N	MEAN	SEMEAN	MIN	MAX
Lordosis					
Quarter 1	17	8.88	1.38	1.31	20.03
Quarter 2	17	10.88	1.47	2.16	26.00
Quarter 3	17	11.30	1.16	5.10	20.26
Quarter 4	17	10.40	1.37	4.10	25.16
Kyphosis					
Quarter 1	17	9.07	1.13	2.55	19.37
Quarter 2	17	11.18	1.21	6.00	25.59
Quarter 3	17	10.91	0.96	5.02	20.51
Quarter 4	17	8.77	1.02	3.35	22.09

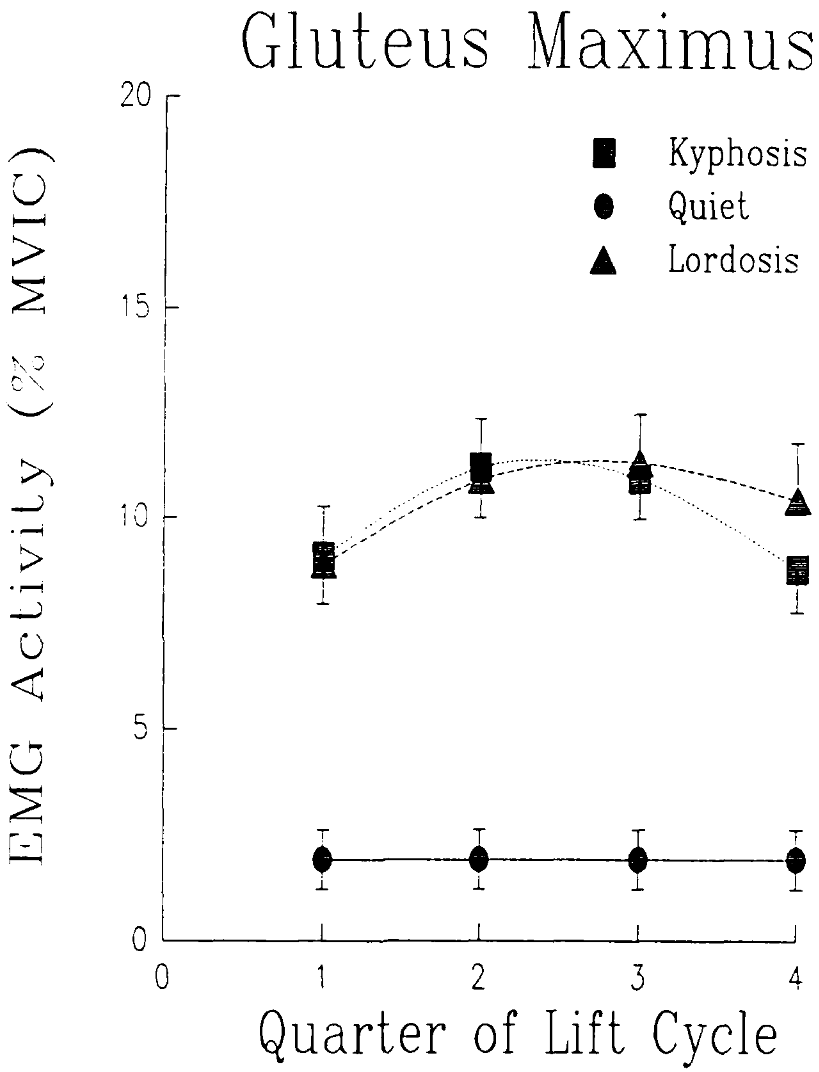

Figure 15. EMG Activity (% MVIC) - Gluteus Maximus.

Table 24. EMG Activity (% MDA) - Gluteus Maximus

Style/Phase	N	MEAN	SEMEAN	MIN	MAX
Lordosis					
Quarter 1	17	26.49	2.03	9.01	38.53
Quarter 2	17	34.09	1.88	14.54	46.26
Quarter 3	17	37.00	1.43	25.75	50.18
Quarter 4	17	31.88	1.61	20.24	43.74
Kyphosis					
Quarter 1	17	28.59	2.00	9.51	39.23
Quarter 2	17	36.07	1.51	25.03	47.52
Quarter 3	17	35.59	1.15	24.71	41.16
Quarter 4	17	27.63	1.48	15.71	39.68

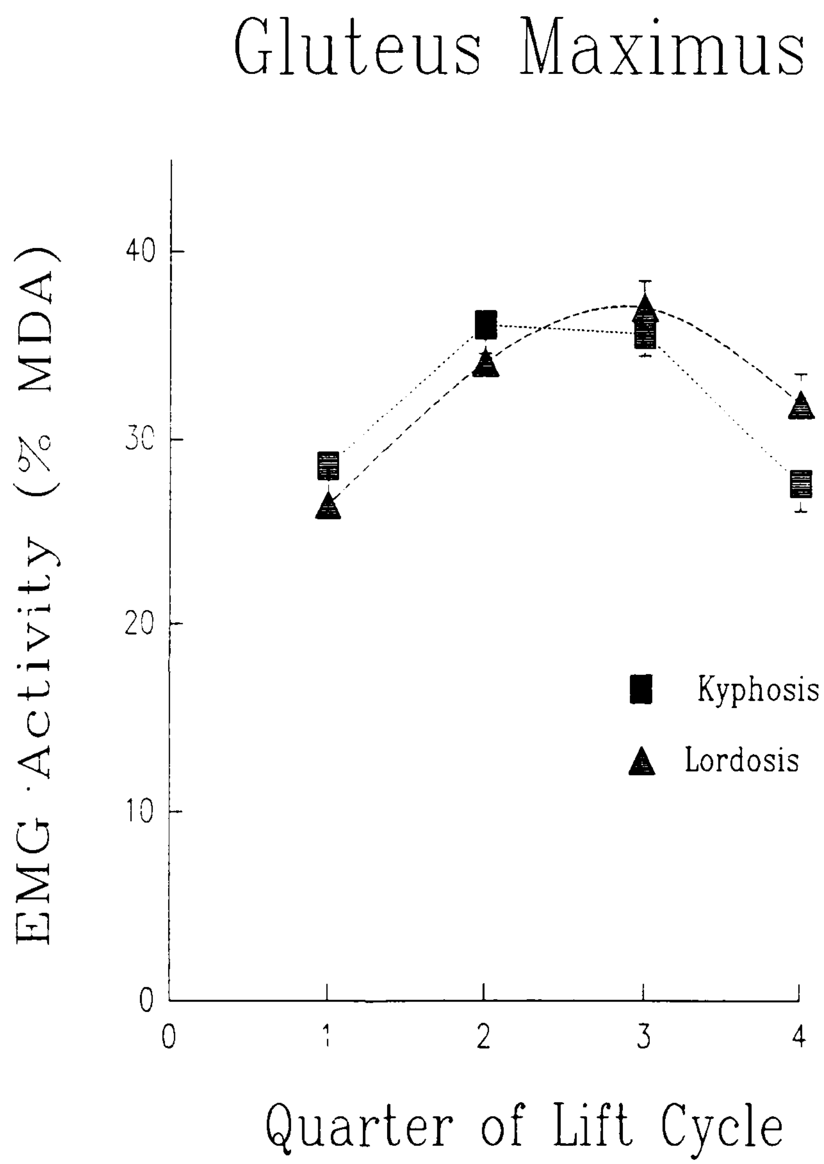

Figure 16. EMG Activity (% MDA) - Gluteus Maximus.

(fig 16; tab. 24). Quarter three had higher ($p<.05$) values of EMG activity than quarter four in the lordotic and kyphotic lifts (fig. 10). Quarter two had increased ($p<.05$) EMG activity over quarter four in the kyphotic lift but not the lordotic lift (fig. 16; tab. 24).

Biceps Femoris

% MVIC. Biceps femoris muscle EMG activity was at its minimal level in quarter one and increased in intensity throughout the remaining three quarters of the lordotic lift (tab. 25; fig. 17). In the kyphotic lift the EMG activity increased from quarter one to quarter three and then decreased in quarter four (tab. 25; fig. 17). Differences ($p < .05$) in EMG activity were found between subjects and between quarters within a lift (tab. 11). The lordotic lift had greater ($p<.05$) EMG activity in quarter four, but no other differences ($p<.05$) were found between styles when compared in the same quarter of a lift (tab. 11). No difference in EMG activity was found between the first two quarters in the lordotic lift (tab. 25; fig. 17). Differences ($p<.05$) were found in the EMG activity between the first and third quarters in both lifting styles and between the first and fourth in the lordotic lift (fig. 17). Differences ($p<.05$) in EMG activity were found

Table 25. EMG Activity (% MVIC) - Biceps Femoris

Style/Phase	N	MEAN	SEMEAN	MIN	MAX
Lordosis					
Quarter 1	17	5.23	0.75	2.43	14.93
Quarter 2	17	5.84	0.73	2.70	14.13
Quarter 3	17	8.28	1.61	2.39	29.32
Quarter 4	17	8.73	1.62	2.16	27.29
Kyphosis					

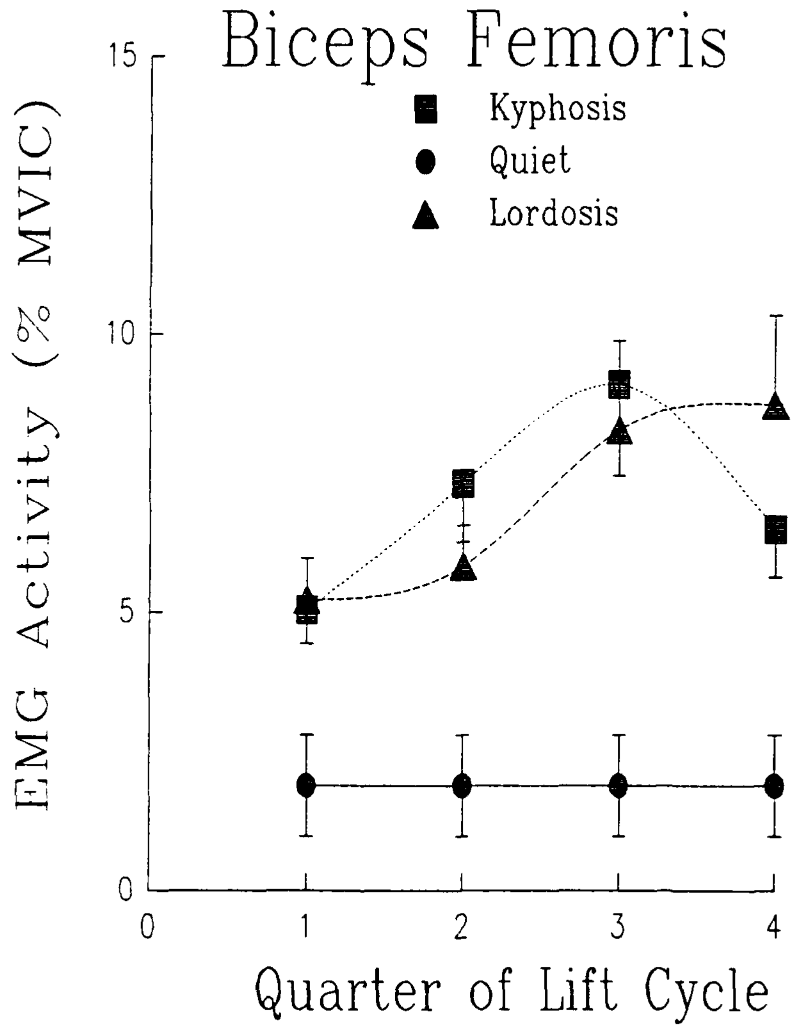

Figure 17. EMG Activity (% MVIC) - Biceps Femoris.

between the third and fourth quarters in the kyphotic lift, but not in the lordotic lift (fig. 17).

% MDA. A similar pattern was seen when doing the % MDA analysis of EMG activity. Differences ($p<.05$) were seen between subjects and between quarters within a lift style (tab. 12). No differences ($p<.05$) were seen between quarters one and two in either style of lift (tab. 26; fig. 18). Quarter one had less ($p<.05$) EMG activity that quarter three in both lifting styles (fig. 18). Quarter four had greater ($p<.05$) EMG activity than quarter one and two in the lordotic lift, but no difference was found in the kyphotic lift (tab. 26; fig. 18). No difference ($p<.05$) in EMG activity was seen between quarter one and four in the lordotic lift or between quarters two and three in both styles of lifting, while quarter four had a higher level in the kyphotic lift (fig. 18).

Semitendinosus

% MVIC. Differences ($p<.05$) in EMG activity were found between subjects, and between quarters of the lift (tabs. 13). No difference ($p<.05$) in EMG activity was found between quarters one and four and quarters one and two regardless of lifting style (tab. 27; fig. 19). A difference ($p<.05$) in EMG activity was found between quarters one and three in the lordotic lift but not in the kyphotic lift (fig. 19; tabs.

Table 26. EMG Activity (% MDA) - Biceps Femoris

Style/Phase	N	MEAN	SEMEAN	MIN	MAX
Lordosis					
Quarter 1	17	23.02	2.56	11.41	39.57
Quarter 2	17	24.99	2.02	12.68	37.60
Quarter 3	17	30.56	1.50	21.14	44.31
Quarter 4	17	30.44	2.28	15.09	44.26
Kyphosis					
Quarter 1	17	23.39	2.16	9.01	39.91
Quarter 2	17	27.77	1.75	16.78	41.27
Quarter 3	17	31.62	1.42	15.16	41.15
Quarter 4	17	24.98	2.34	4.30	40.54

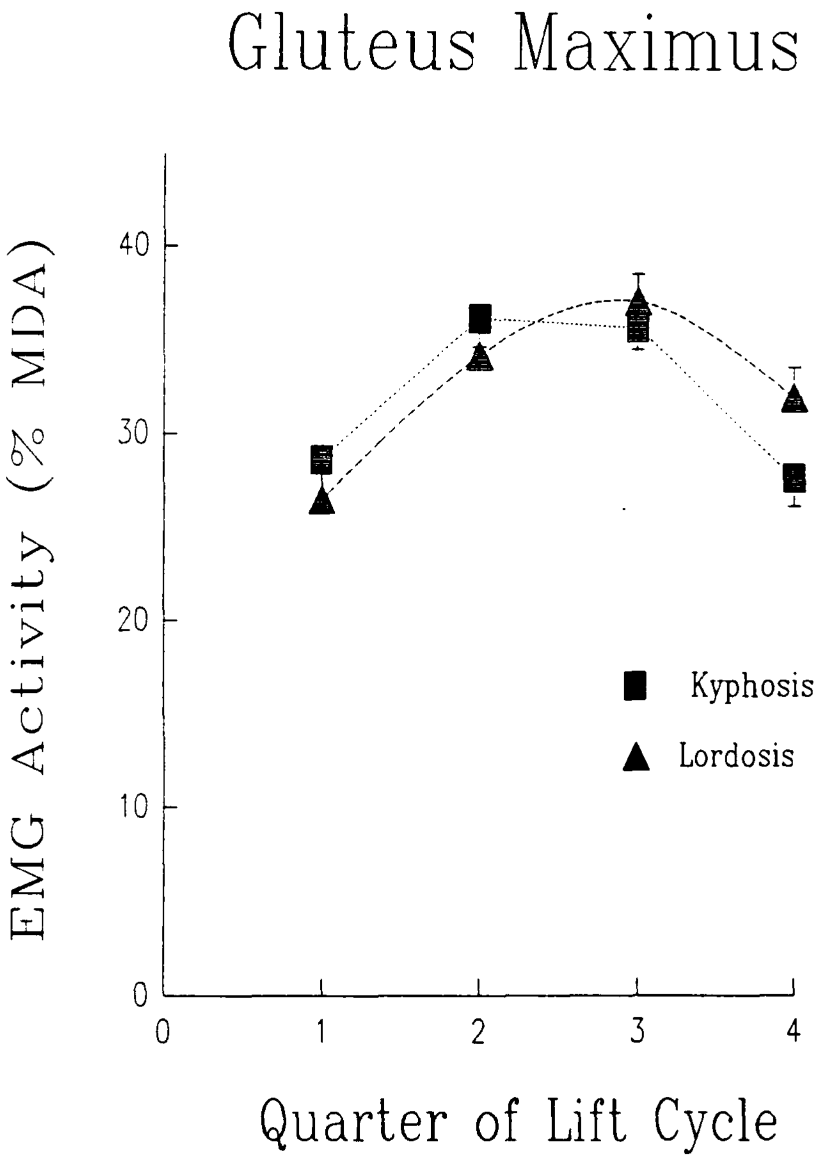

Figure 18. EMG Activity (% MDA) - Biceps Femoris

Table 27. EMG Activity (% MVIC) - Semitendinosus

Style/Phase	N	MEAN	SEMEAN	MIN	MAX
Lordosis					
Quarter 1	17	4.04	0.60	0.37	8.84
Quarter 2	17	4.43	0.67	0.36	9.31
Quarter 3	17	5.35	1.02	0.37	14.75
Quarter 4	17	4.96	0.97	0.37	14.02
Kyphosis					
Quarter 1	17	4.77	0.82	0.38	11.24
Quarter 2	17	5.35	0.89	0.39	12.54
Quarter 3	17	5.44	0.97	0.37	14.04
Quarter 4	17	4.32	0.85	0.37	12.03

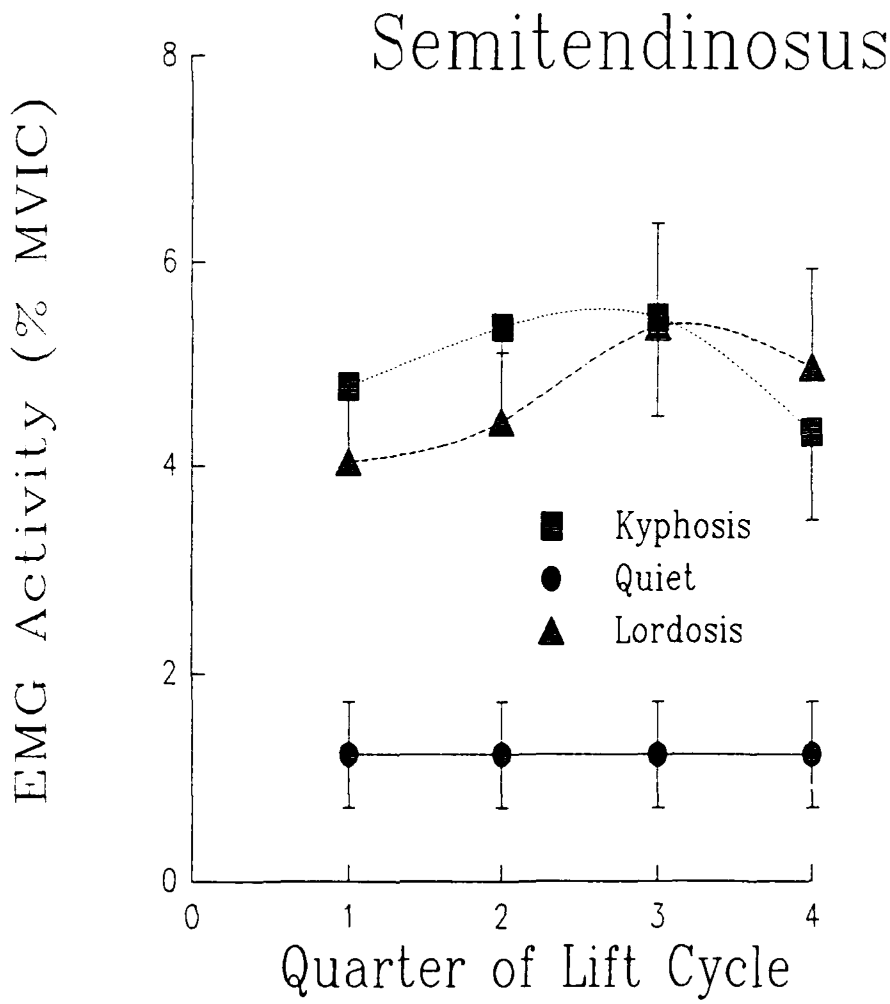

Figure 19. EMG Activity (% MVIC) - Semitendinosus.

27). No differences ($p<.05$) were found between quarters two and three in either style of lift, or between quarters two and four and quarters three and four in the lordotic lift (fig. 13). Differences were found ($p<.05$) between quarters two and four and between quarters three and four in the kyphotic lift (tab. 27; fig 13).

% MDA. Differences ($p<.05$) were seen between subjects, between quarters within a lifting style and in the timing of EMG activity (lift vs style interaction) (tab. 14). No differences were found between quarters one and two or between quarters two and three in either style of lift (fig. 14). Differences ($p<.05$) were found between quarters two and four, quarters one and four and quarter three and four in the kyphotic lift and between quarter one and quarter three in the lordotic lift (fig. 14). No other differences were found.

Table 28. EMG Activity (% MDA) - Semitendinosus

Style/Phase	N	MEAN	SEMEAN	MIN	MAX
Lordosis					
Quarter 1	17	29.46	2.17	12.58	44.27
Quarter 2	17	30.27	1.73	18.57	44.79
Quarter 3	17	33.55	1.45	22.38	46.73
Quarter 4	17	30.83	1.77	20.31	45.22
Kyphosis					
Quarter 1	17	30.45	1.90	15.56	44.23
Quarter 2	17	33.06	1.51	20.39	44.69
Quarter 3	17	32.01	1.28	21.77	42.91
Quarter 4	17	25.60	1.95	14.72	42.88

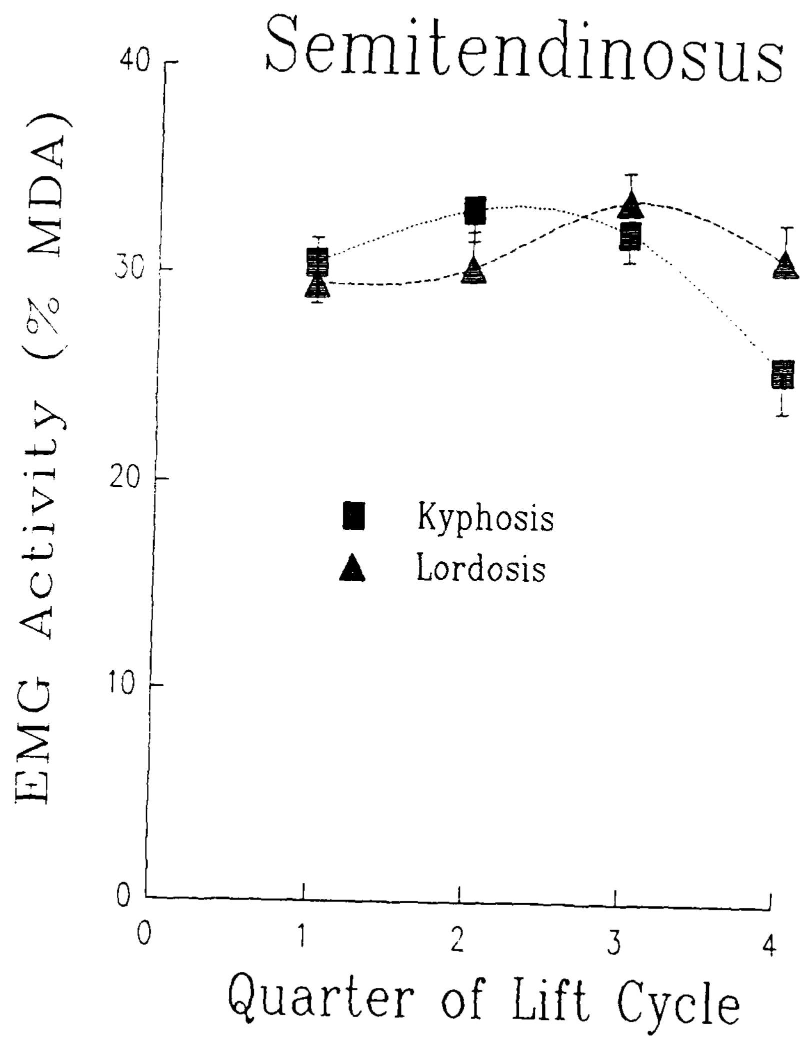

Figure 20. EMG Activity (% MDA) - Semitendinosus.

Discussion

This study used two methods of quantifying EMG activity, percent of maximal voluntary isometric contraction (% MVIC) and percent of maximum intensity during activity (% MDA). The quantification of EMG as % MVIC allows comparisons of EMG signal intensity between different muscle groups. This comparison can help determine which muscle group is most active during an activity. However, there are problems that must be considered when using % MVIC as the referencing standard. Problems include: using an isometric contraction to standardize a dynamic event, proper joint angle and testing procedure to get the maximum EMG signal, and subject motivation and effort. Use of % MDA to quantify EMG signals reveals the EMG activity pattern of each muscle. Comparison of signal intensity between different muscles is not possible, since each muscle is normalized against its own EMG signal during the activity and there is no way to know the absolute intensity of the signal recorded. However, advantages exist for the use of % MDA as a referencing standard. Among its advantages are: dynamic referencing standard (the EMG signal used for normalization is recorded during the actual activity), eliminates problems with subject motivation and choosing of the proper joint angle and testing procedure for maximum EMG signal. For the most part, the two methods of analysis yielded similar results during this study.

This study investigated squat lifting and the effect varying the lumbar posture had on the EMG activity of the hip extensor (GM, BF, and ST) muscles and trunk muscles (RA, AO, ES, and LD). The muscles were chosen because of: anatomical connections to the thoracolumbar fascia, and potential contributions to a lift. A successful squat lift involves raising an object and keeping it under control until completion of the lift. The initial portion of the lift plays the largest role in the success or failure of the lift. It is in the initial portion of the lift that the inertia of the load is overcome and the greatest stress is placed on the lumbo-sacral spine (Frievalds, 1984). Therefore, differences in EMG activity observed during this period, or between the first period and subsequent periods carries the greatest significance. This discussion will center on differences between styles in the first quarter and differences between the first quarter and subsequent quarters within a single style of lift.

Two distinct patterns of EMG activity, independent of lumbar spine posture, were seen in this study: 1) a trunk muscle pattern (LD, AO, RA, and ES) which showed more EMG activity in the early portions of the lift cycle and decreasing intensity as the lift progressed (figs. 7-14), and 2) a hip extensor pattern for which the hip extensor muscles (GM, BF, ST) had their lowest level of EMG activity in the first quarter, which increased in the second and third quarters, before levelling off or decreasing in the last quarter (figs. 15-20). Generally, the patterns of EMG activity of the ES and AO seen during this study were consistent with the patterns reported by other researchers (Delitto, 1985; Hart 1987). This study differed from other studies in that all trunk muscles (ES, AO, RA, and LD) showed greatest EMG activity in the first quarter. The EMG activity decreased as the lift in each of the following phases. Delitto (1985) found this pattern in the AO muscle and the ES muscle in a lordotic lift, but not in the kyphotic lift. In the kyphotic lift the ES EMG activity began at a lower level (when compared to the same time period in the lordotic lift) and increased during the lifting cycle (Delitto, 1985). One possible reason for the different ES EMG patterns may be the procedures used to determine starting and ending points for the lift cycle. Delitto (1985) used a pressure-sensitive switch to indicate the beginning of the lift, and a single axis electrogoniometer secured at the hip to indicate the end of the lift. This study used video data to determine starting and ending points. Therefore, the lift cycle may be of different lengths in the different studies. This might cause the normalization of the lift cycle and EMG activity to not be exactly equivalent. The trunk muscles produced similar EMG activity patterns (% MVIC and % MDA), regardless of the style of squat lifting. However, the EMG activity recorded in the RA, AO and LD appears to indicate a relatively minor contribution to the success of the lift (fig. 7, 9, 13). The RA EMG activity (% MVIC) during the lift did not differ significantly from that recorded during quiet standing in any time period of the lift (fig. 7). The AO and LD EMG activity (% MVIC) did not differ from quiet standing in quarters three or four (fig. 9, 13). Thus, the contributions of the AO, RA and LD is finished by the half-way point of the lift.

In the hip extensor muscles the pattern of EMG activity differed from that seen in the trunk muscles. The EMG activity in the hip extensor muscles studied (GM, BF and ST) was lowest in the first quarter (figs. 15-20). The activity increased through quarters two and three, before plateauing or decreasing in the final quarter. No differences were seen in hip extensor muscle EMG activity between the two lifting styles in the first three quarters. It was not until the fourth quarter that differences were seen between the two lifting styles. The BF (% MVIC) and the ST (% MDA) showed greater EMG activity in the lordotic lift during the fourth quarter. The ST also showed a different ($p<.05$) relationship between timing and EMG (% MDA) activity (style vs. quarter). These results do not show the hip extensor muscles (GM, BF, and ST), acting through the thoracolumbar fascia, as providing any greater contribution in the kyphotic lift when compared to the lordotic lift under the test conditions of this study.

In this study, only the ES muscle showed differences between the two lifting styles during the initial period of the lift. All other muscles, trunk (RA, LD, AO) and hip extensor (GM, ST, BF), showed similar patterns of EMG activity regardless of lumbar posture until the end of the lift. Plotting the ES EMG activity revealed different shapes of EMG activity in the two lifting styles (Figs. 13, 14). In the lordotic lift the decrease of the EMG activity took on a sigmoidal shape while in the kyphotic lift the EMG activity decreased in a gentle arc. The lordotic style had greater EMG activity in the first quarter while in the third and fourth quarters the activity in the kyphotic lift was greater.

It has been speculated that the decreased ES EMG activity during the early stages in the kyphotic lifting style may be due to greater efficiency of the ES muscles because of the muscles being in a prestretched condition (Delitto, 1985). However, this does not appear to be the case. It appears that a different ES muscle activity pattern is employed in the kyphotic lift. Using % MDA to normalize the EMG activity revealed the relative contribution of each muscle compared to its peak amplitude during the activity. If differences seen in the first quarter (% MVIC) were primarily due to increased efficiency of the ES muscles, then a similar muscle activity pattern should have been seen (% MDA) in the lordotic and kyphotic lifts. This was not observed in the ES, therefore, it was concluded that different mechanisms were at work in the two lifting styles.

The remaining trunk muscles (RA, AO, and LD) revealed similar patterns of EMG activity in the lordotic and kyphotic lifting styles. The activation of these muscles was minimal (< 5% of MVIC) indicating that their role in providing stability to the spine during the lift may be limited. This low activity of the RA and AO is consistent with the results reported by other researchers and suggests that the role of intra-abdominal pressure as a support mechanism may not be as great as thought (Ekholm, 1982; Hemborg, 1983; & McGill 1987, 1990). The low level of activity suggest that any contributions of these muscles to the lift through the thoracolumbar fascia may also be limited. Delitto (1985) showed greater activation of the AO muscles during both styles of lifting. This may be due to using a different method of normalizing the muscle activity during the lift.

Lindh (1989), Hart (1987) and Adams (1980) report that in a kyphotic (i.e. flexed) posture the ligaments are on a stretch and provide counterbalancing force to the trunk. Hart (1987) termed this phenomenon as 'hanging on ligaments'. A potential danger of ligamentous support is that the forces produced by ligaments generally have a shorter lever arm than the muscle forces so they may be subject to extremely high loads if they are the main support during a lift (Lindh, 1989). To protect the ligaments and the spine, ES muscles should be active at the beginning of the lift, but no motion of the spine should occur until the inertia of the load is overcome (Davis, 1965; Lindh, 1989). After the initial inertia of the load is overcome the spine extends to the end of the lifting cycle (Davis, 1965).

In this study it was observed that the ES EMG activity is higher in the lordotic lift during the first quarter when compared to the kyphotic lift, no differences were seen in the other trunk muscles or the hip extensor muscles. The clinical implications are that lifting with the lumbar spine in a lordotic position is advantageous. The increased EMG activity of the ES muscles in a lordotic lift causes increased compression across the lumbo-sacral joint (Frievalds, 1984). However, the lumbar spine provides more resistance to compressive forces than bending forces and is better able to deal with increased compression (Lin, 1978). Also, with the lumbar spine in a lordotic posture the ligaments are not on stretch and the antiflexion moment is provided to a greater extent by muscle contraction thus protecting the ligaments from excessive strain (Hart, 1987; Lindh, 1989). These factors may help explain why decreased isometric endurance of the back extensor muscles is a predictor of low back pain (Beiring-Sorensen, 1989). A person may not have the endurance needed to protect the ligaments and the lumbar spine from undue stress when doing repetitive lifting.

In the later stages of the lift (quarters three and four) the ES EMG activity is greater in the kyphotic lift and the hip extensor activity (GM, BF, and ST) is greater in the lordotic lift. This activity may contribute to the final restoration of the upright posture. In the lordotic lift the spine should already be in a lordotic posture and ES muscle activity is not needed to restore the normal lordotic curve. Final restoration of upright posture may be accomplished through hip extension. The increased ES activity observed In the kyphotic lift may be a result of the restoration of the normal lordotic curve. Lumbar extension is needed for the final attainment of the fully upright posture in the kyphotic lift.

CHAPTER 5

SUMMARY AND CONCLUSION

Summary

The purpose of this study was to determine the function of muscles that are anatomically related to the thoracolumbar fascia and lumbar spine during a squat lift and to see the effects of varying the lumbar posture. The research hypothesis was that lifting in a kyphotic posture would result in greater EMG activity in the hip extensor muscles. The hip extensor muscles were thought to be anatomically situated to extend the trunk. Seven muscles (RA, AO, ES, LD, GM, BF, ST), were chosen for this study because of their attachment to the thoracolumbar fascia and posterior ligamentous system.

Seventeen male subjects recruited from the University of Kentucky performed three squat lifts in each of the lumbar postures. Each lift was normalized to a percentage of total time and divided into four equal parts. Likewise, the EMG activity recorded in each muscle was also normalized. Two methods of normalization were used: 1) a percentage of the muscle's maximum isometric contraction (% MVIC) and 2) a percentage of the maximum EMG activity recorded in that muscle during the lift (% MDA). Analysis revealed two distinct patterns of EMG activity: a trunk muscle pattern and a hip extensor muscle pattern. In the trunk muscle pattern greatest activity was observed in the first quarter. This activity decreased as the subject moved from the squat position to the upright position. In the hip extensor muscle pattern the smallest amount of EMG activity was observed in the first quarter. The EMG activity increased in the second and third quarters before leveling off or decreasing in the fourth quarter. A 2 X 4 repeated measure ANOVA was used to statistically analyze the EMG activity recorded in each muscle. Lumbar posture (lordotic vs. kyphotic) and timing (quarter 1, quarter 2, quarter 3, and quarter 4) were analyzed for each muscle. Analysis revealed differences between subjects and between different time phases within a style of lifting. No differences were observed during the early stages of the lift when comparing the two styles in any muscle except the ES muscles. Therefore, the research hypothesis is rejected and the null hypothesis accepted.

Conclusions

1) Two distinct patterns of EMG activity were seen in this study: a trunk muscle (RA, AO, ES, LD) pattern and a hip extensor muscle (GM, BF, ST) muscle pattern.

2) In the early stages of the lift no difference was seen in the hip extensor (GM, BF, ST) EMG activity between the two lifting styles.

3) Different ES EMG activity patterns were seen when comparing the different lifting styles. Less EMG activity was seen in the first quarter with the lumbar spine in a kyphotic (flexed) posture, when compared to the lordotic (extended) posture. It is thought that more of the load is being borne by the ligaments in the kyphotic. Conversely, the increased activity seen with the lordotic lift suggest that more of the load is being supported by the muscles.

4) It appears that the main function of the trunk muscles and the posterior ligamentous system is to provide stability to the lumbar spine during a lift, especially the early stages, i.e. until the inertia of the load is overcome.

5) The trunk muscles (AO, RA, LD), other than the ES, play a relatively minor role in the squat lift, regardless of the posture.

6) Clinically, lifting with the lumbar spine in a lordosis is advantageous. The muscles appear to bear more of the load in providing stability to the spine and the muscles thereby protect the inert tissues. However, there are increased compressive forces on the lumbar spine in this posture, but the lumbar spine can withstand compressive forces better than shear or torsion forces.

Recommendations for future study.

This study did not reveal any difference in EMG activity between the two lifting styles except in the ES muscles. It is possible that the weights chosen were not heavy enough to show a difference. Heavier loads could be used in future studies to see if different EMG patterns are seen. In addition, analysis of repeated lifts or lifting after the muscles are fatigued, should be done as this may more closely simulate the work environment. Video analysis of the subjects while they are lifting, in conjunction with the EMG, so that the EMG activity patterns can be coordinated with the movements.

APPENDIX A

Consent for Research Study

"EMG Activity of selected lumbar and hip muscle during a Squat Lift: Effect of Varying the Lumbar Posture"

I, ____, freely and voluntarily agree to participate in a thesis research project under the direction Jim Vakos, Dr. Arthur Nitz, Dr. Joseph Threlkeld, and Dr. Rob Shapiro. This project is to be conducted at Wenner-Gren Biomechanics Laboratory at the University of Kentucky.

I understand that knowledge of the mechanisms involved and the forces incurred while lifting are important in the development of safe lifting techniques. The purpose of this research is to determine which of the trunk and hip muscles are used when lifting a crate of 35.25 pounds (for males, 24 pounds for females), from the floor. I understand that the benefits of this research will not effect me directly, but the knowledge gained will have a positive influence upon injury prevention.

In agreeing to participate in this study I understand that I will be required to lift either a 35.25 (males) pound or a 24 (females) pound crate using a squat lift. A squat lift is one in which the hips and knees are bent to lower the body down to the object to be lifted. A total of six lifts will be performed. Three of the lifts with the back in a "bowed-in" position and three with the back in a "bowed-out" position. I understand that I will be required to come to Wenner-Gren Biomechanics laboratory one time and this session will last approximately one hour. I understand that surface electrodes and reflective markers will be placed on my body. I also understand that I will be required to give a maximal exertion of my abdominal, back extensor and hip extensor muscles.

I understand that participation is voluntary; refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled. I understand that no compensation is being offered or is available for my participation.

I understand that I cannot participate in this study if I have had an episode of low back pain within the last six months or I have suffered an injury to my knees or hips which interferes with my ability to squat.

I understand that review of the literature and experience of the researchers indicate that these weights and procedures are within the safe and acceptable limits and represent minimal risk of injury. I understand that there is a chance of suffering a low back strain secondary to participation.

I understand that in the event of physical injury resulting from this research project in which I am participating, no form of compensation is available. A physical therapist will be present at all times during the research project to provide assistance in the event of an unexpected injury. However, any medical treatment will be provided at my own expense or at the expense of my health care insurer. I also understand that if I desire further information about this matter, I should contact Jim Vakos, P.T., at 273-5575.

I authorize Jim Vakos and the Department of Health, Physical Education and Recreation and the Physical Therapy Department to keep, preserve, use and dispose of the findings from this research with the provision that my name will not be associated with any of the results.

I have been given the right to ask, and have answered, any questions concerning the procedures to be used during this research. Questions have been answered to my satisfaction. I understand that my confidentiality and anonymity will be protected. I further understand that I have the right to terminate my involvement in this project at any time, without sustaining any form of penalty. I have read and understand the contents of this form and received a copy.

Subject ______________________________ Date ___________________

Witness ______________________________ Date ___________________

I have explained and defined in detail the research procedure in which the subject has consented to participate.

Principle Investigator ________________________ Date ________

APPENDIX B

Medical History Questionnaire

NAME ____________________

AGE ______

SOCIAL SECURITY NUMBER __________-_____-__________

Answer the following questions by marking the appropriate response.

1. Have you ever suffered an injury to your low back or an episode of low back pain?

   ____ YES

   ____ NO

2. If yes, when did this incident occur?

   ____ LESS THAN SIX MONTHS AGO

   ____ MORE THAN SIX MONTHS AGO

3. Have you ever suffered an injury to your hips or knees, or suffer from any condition that would prevent you from squatting?

   ____ YES

   ____ NO

4. To the best of your knowledge do you suffer from any condition that would prevent you from exerting yourself, i.e. cardiac precautions, emphysema, etc.?

   ____ YES

   ____ NO

BIBLIOGRAPHY

Adams, M. A., Hutton, W. C., & Stott, J. R. R. (1980). The resistance to flexion of the lumbar intervertebral joint. Spine, 5, 245-252.

Andersson, G. B. J. (1985). Loads on the lumbar spine: In vivo measurement and biomechanical analysis. In Winter, D. A. (Ed.), Biomechanics IX-B (pp. 32-35). Champaign, IL: Human Kinetic Publishers.

Andersson, G. B. J. (1981). Epidemiologic aspects of low back pain in industry. Spine, 6, 53-57.

Andersson, G. B. J., Ortengren, R. O., & Heberts, P. (1977). Quantitative electromyographic studies of back muscle activity related to posture and loading. Orthopedic Clinics of North America, 8, 85-96.

Andersson, G. B. J., Ortengren, R. O., & Nachemson, A. (1976). Quantitative studies of back loads in lifting. Spine, 1, 178-185.

Aspden, R. M. (1989). The spine as an arch: A new mathematical model. Spine, 14, 266-274.

Bartelink, D. L. (1957). The role of abdominal pressure on the lumbar intervertebral discs. Journal of Bone and Joint Surgery (British ed.), 39, 718-725.

Beiring-Sorensen, F., Thomsen, C. E., & Hilden, J. (1989). Scandinavian Journal of Rehabilitative Medicine, 21, 151-157.

Bigos, S. J., Spengler, D. M., Martin, N. A., Zeh, J., Fisher, L., Nachemson, A., & Wang, M. H. (1986). Back injuries in industry: A retrospective study, II. Injury factors. Spine, 11, 246-251.

Bogduk, N., & Twomey, L. T. (1987). Clinical anatomy of the lumbar spine. New York: Churchill Livingstone.

Bogduk, N., & Macintosh, J. E. (1984). The applied anatomy of the thoracolumbar fascia. Spine, 9, 164-170.

Bush-Joseph, C., Schipplein, O., & Andersson, G. B. J. (1988). Influence of dynamic factors on the lumbar spine moment in lifting. Ergonomics, 31, 211-216.

Carlsoo, S., (1961). The static muscle load in different work positions: an electromyographic study. Ergonomics, 4, 193-211.

Cook, T. C., & Newman, D. A. (1987). The effect of load placement on the emg activity of low back muscles during load carrying by men and women. Ergonomics, 30, 1413-1423.

Davis, P. R., Troup, J. D. G. & Burnard, J. H. (1965). Movements of the thoracic and lumbar spine when lifting: a chrono-cyclophotgraphic study. Journal of Anatomy - London, 99, 13-26.

Delitto, R. S., Rose, S. J., & Apts, D. W. (1987). Electromyographic analysis of two techniques for squat lifting. Physical Therapy, 67, 1329-1334.

Ekholm, J. Arborelius, U. P., & Nemeuth, G. (1982). The load on the lumbo-sacral joint and trunk muscle activity during lifting. Ergonomics, 25, 145-161.

Freivalds, A., Chaffin, D. B., Garg, A., & Lee, K. S. (1984). A dynamical biomechanical evaluation of lifting, maximum acceptable loads. Journal of Biomechanics, 17, 251-262.

Gagnon, M. Sicard, C., & Drouin, G. (1985). Evaluation of loads on the lumbar spine with motion analysis techniques and a static plana model. In Winter, D. A. (Ed.), Biomechanics IX-B (pp. 44-49). Champaign, IL: Human Kinetic Publishers.

Gracovetsky, S. (1988). The Spinal Engine. New York, NY: Springer-Verlag

Gracovetsky, S., Farfan, H. & Hueller, C. (1985). The abdominal mechanism. Spine, 10, 317-324.

Gracovetsky, S., Farfan, H. F., & Lamy, C. (1981). The mechanism of the lumbar spine. Spine, 6, 249-261.

Hart, D. L., Stobbe, T. J., & Jaraeid, M. (1987). Effect of lumbar posture on lifting. Spine, 12, 138-145.

Hemborg, B., Moritz, U., Hemborg, J., Lowing, H., & Akesson, I. (1983). Intra-abdominal pressure and trunk muscle activity during lifting and effect of abdominal training on healthy subjects. Scandinavian Journal of Rehabilitative Medicine, 15, 183-196.

Jonsson, B. (1985) The value of electromyographic measures in the assessment of muscular load and fatigue in work place tasks. In Winter, D. A. (Ed.), Biomechanics IX-B (pp. 3-5). Champaign, IL: Human Kinetic Publishers.

Joseph, J., & Williams, P. L. (1957). Electromyography of certain hip muscles. Journal of Anatomy, 91, 286-294.

Kippers, V., & Parker, A. W. (1984). Posture related to myoelectric silence of erector spinae during trunk flexion. Spine, 9, 740-745.

Lin, H. S., Liu, Y. K., & Adams, K. H. (1978). Mechanical response of the lumbar intervertebral joint under physiological (complex) loading. Journal of Bone and Joint Surgery, 60-A, 41-55.

Lindh, M. (1989) Biomechanics of the lumbar spine. In Nordin, M., & Frankel, V. H. (ed). Basic biomechanics of the musculoskeletal system (2^{nd} ed.). Philadelphia: Lea and Febiger

McGill, S. M., & Sharratt, M. T. (1990). Relationship between intra-abdominal pressure and trunk EMG. Clinical Biomechanics, 5, 59-67.

McGill, S. M., & Norman, R. W. (1987). Reassessment of the role of intra-abdominal pressure in spinal compression. Ergonomics, 30, 1565-1588.

McGill, S. M., & Norman, R. W. (1986). Partitioning of the L_4-L_5 dynamic moment into disc, ligamentous and muscular components during lifting. Spine, 11, 666-678.

McGill, S. M., & Norman, R. W. (1985). Dynamically and statically determined low back movement during lifting. Journal of Biomechanics, 18, 877-885.

Macintosh, J. E., & , N. (1987). The biomechanics of the thoracolumbar fascia. Clinical Biomechanics, 2, 78-83.

Ortengren, R., Andersson, G. B. J., & Nachmeson, A. L. (1981). Studies of relationships between lumbar disc pressure, myoelectric back muscle activity and intra-abdominal (intragastric) pressure. Spine, 6, 98-103.

Panjabi, M. H., Tech, D., & White, A. (1980). Basic biomechanics of the spine. Neurosurgery, 7, 76-93.

Portnoy, H., & Morin, F. (1958). Electromyographic study of postural muscles in various positions and movements. American Journal of Physiology, 186, 122-126.

Seroussi, R. E., & Pope, M. E. (1987). The relationship between trunk muscle electromyography and lifting moments in the sagittal and frontal planes. Journal of Biomechanics, 20, 135-146.

Sihvonen, T., Partanen, J. & Hanninen, O. (1988). Averaged (rms) surface emg in testing back function. Electromyography Clinics in Neurophysiology, 28, 335-339.

Spengler, D. M., Bigos, S. J., Martin, N. A., Zeh, J., Fisher, L. & Nachemson, A. (1986). Back injuries in industry: A retrospective study. Overview and cost analysis. Spine, 11, 241-245.

Sullivan, M. S. (1989). Back support mechanisms during manual lifting. Physical Therapy, 69, 38-46.

Tanii, K., & Masuda, T. (1985). A study by EMG stick diagrams of the muscular activities in the trunk flexion and extension movement. Ergonomics, 28, 895-904.

Troup, J. D. G. (1977). Dynamic factors in the analysis of stoop and crouch lifting methods: A methodological approach to the development of safe materials handling standards. Orthopedic Clinics of North America, 8, 201-209.

Zetterberg, C., Andersson, G. B. J., & Schultz, A. B. (1987). The activity of individual trunk muscles during heavy physical loading. Spine, 10, 1035-1040.

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